



A Dictionary of Science

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LOW-PRICED EDITION

Fifth Edition



Animesh Nagar

A DICTIONARY OF SCIENCE

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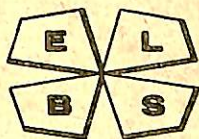
REVISED FOR THE FIFTH

EDITION BY

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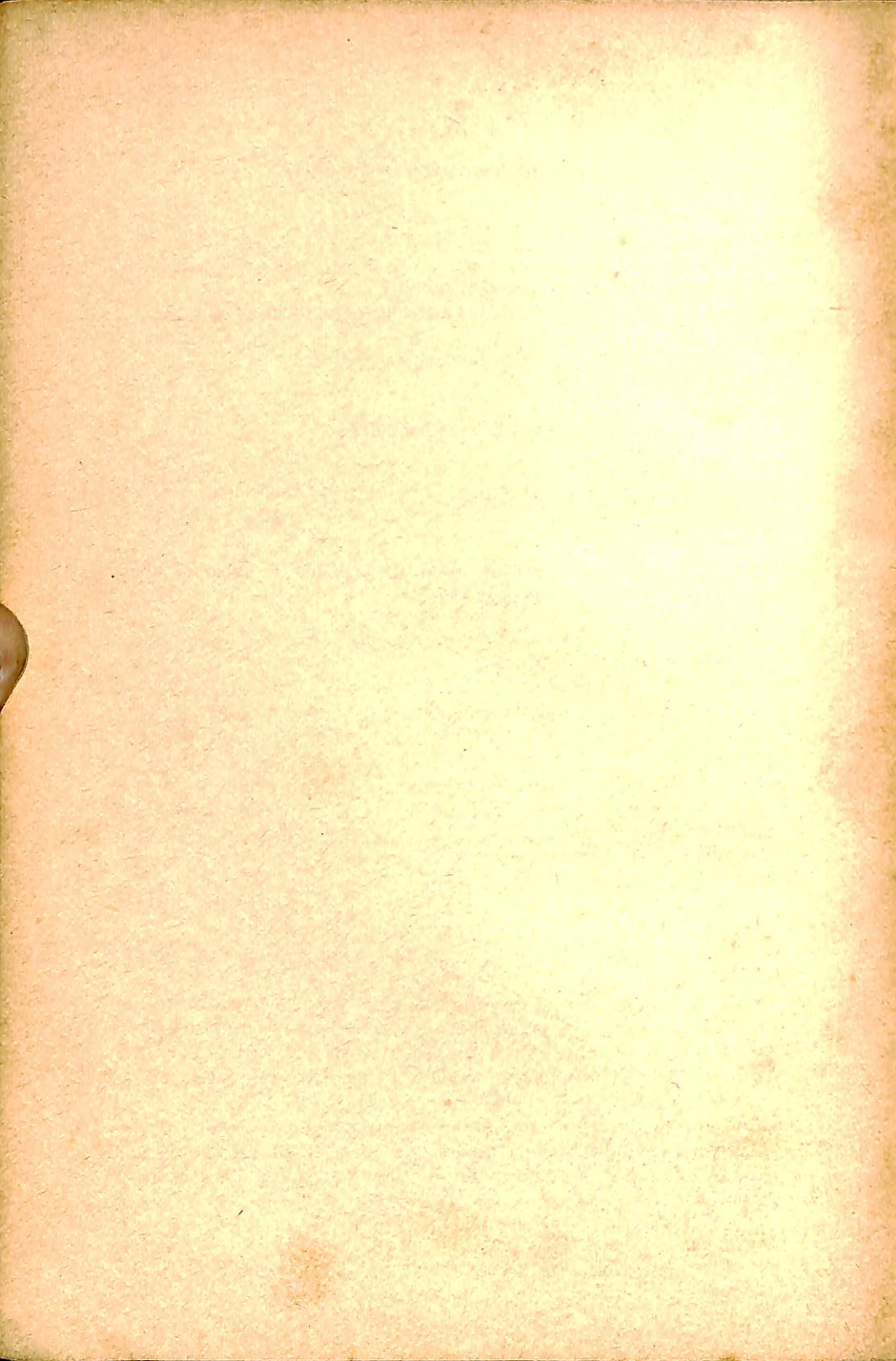


THE ENGLISH LANGUAGE BOOK SOCIETY
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Abbreviations used in the Text

At. No.	Atomic number
A.W.	Atomic weight
(astr.)	Astronomy; as used in astronomy
(bio.)	Biochemistry; as used in biochemistry (or biology)
b.p.	Boiling point
(chem.)	Chemistry; as used in chemistry
conc.	Concentrated
f.p.	Freezing point
(math.)	Mathematics; as used in mathematics
m.p.	Melting point
(phot.)	Used in Photography
(phys.)	Physics; as used in physics
r.d	Relative density

Abbreviations for SI units are used throughout. A table of these abbreviations will be found on page 387.



A

ab- A prefix attached to the names of practical electric units (e.g. *ampere*, *volt*) to indicate the corresponding unit in the *electromagnetic system* (e.g. *abampere*, *abvolt*). See *absolute units*.

Abbe condenser An optical *condenser* used in *microscopes*, consisting of two or three *lenses* having a wide *aperture*. Named after Ernst Abbe (1840-1905).

aberration (astr.) A variation in the apparent position of a *star* or other heavenly body, due to the motion of the observer with the *Earth*.

aberration, chromatic The formation, by a *lens*, of an image with coloured fringes, due to the *refractive index* of *glass* being different for *light* of different *colours*. The light is thus dispersed (see *dispersion of light*) into a coloured band. The effect is corrected by the use of *achromatic lenses*.

aberration, spherical The distortion of the image produced by a *lens* or *mirror* due to different rays from any one point of the object making different angles with the line joining that point to the *optical centre* of the lens or mirror (see *mirrors, spherical*) and coming to a *focus* in slightly different positions.

abiogenesis The hypothetical process by which living *organisms* are created from non-living matter: spontaneous generation.

abrasive A substance used for rubbing or grinding down surfaces; e.g. *emery*.

abscissa of a point *P*. In *analytical geometry*, the portion of the *x axis* lying between the *origin* and a point where the line through *P* parallel to the *y axis* cuts the *x axis*. See Fig. 5 under *Cartesian coordinates*.

absolute Not relative; independent. E.g. *absolute zero* of temperature, as distinct from zero on an arbitrary scale such as the *Celsius temperature scale*.

absolute alcohol *Ethanol* containing not less than 99% pure ethanol by weight.

absolute expansion of a liquid. The true *expansion*, not relative to the containing vessel. The coefficient of absolute expansion is equal to the sum of the coefficient of relative or apparent expansion of the liquid and the coefficient of volume expansion of the containing vessel.

absolute humidity The amount of *water vapour* present in the *atmosphere*, defined in terms of the number of *kilograms* (or grams) of water in one cubic *metre* of air. See also *relative humidity*.

ABSOLUTE THERMODYNAMIC

absolute thermodynamic temperature See *thermodynamic temperature*.

absolute units 1. A system of electrical *units* based on the c.g.s. system; e.g. the *abvolt* which is 10^{-9} practical volts. 2. Any system of units using the least possible number of *fundamental units*. See *SI units*, *coherent units*.

absolute zero The lowest temperature theoretically possible; the zero of *thermodynamic temperature*. $0\text{ K} = -273.15^{\circ}\text{C} = -459.67^{\circ}\text{F}$.

absorbed dose See *dose*.

absorptance α . The ratio of the *flux* absorbed by a body to the flux falling on it. The absorptance of a *black body* is 1.

absorption coefficient α . 1. The ratio of the sound energy absorbed at a boundary to the sound energy falling on it. 2. See *linear absorption coefficient*; *linear attenuation coefficient*.

absorption edge The *X-ray wavelength* at which a discontinuity appears in the intensity of an *X-ray absorption spectrum*.

absorption of gases The *solution of gases in liquids*. Sometimes also applied to the absorption of gases by *solids* when the gas permeates the whole body of the solid rather than its surface. Compare *adsorption*.

absorption of radiation *Radiant energy* is partly reflected, partly transmitted, and partly absorbed by the surface upon which it falls, the absorption being accompanied by a rise in *temperature* of the absorbing body. Dull black surfaces absorb the greatest proportion of the incident energy, and brightly polished (reflecting) surfaces the least. Surfaces which are the best absorbers are also the best radiators. See *absorptance*; *absorption coefficient*.

absorption spectrum A *spectrum* consisting of dark lines or bands obtained when the *light* from a source, itself giving a continuous spectrum, is passed through a *gas* into a *spectroscope*. The dark lines or bands will occur in the same position as the coloured lines in that substance's *emission spectrum* and will be characteristic of the substance. When the absorbing medium is in the *solid* or *liquid state* the spectrum of the transmitted light shows broad dark regions, which are not resolvable into sharp lines. Characteristic *X-ray* and *ultraviolet* absorption spectra are also formed.

absorptivity of a surface. The fraction of the *radiant energy* incident on the surface that is absorbed. This concept has now been replaced by *absorptance*.

abundance The ratio of the number of *atoms* of a particular *isotope* in a mixture of isotopes of an *element*, to the total number of atoms present. Sometimes expressed as a percentage, e.g. the abundance of $^{235}_{92}\text{U}$ in natural uranium is 0.71%.

acceleration a . The rate of change of *velocity*; measured as a change of velocity per unit time.

acceleration of free fall Acceleration due to gravity. The *acceleration* of a body falling freely in a *vacuum*; varies slightly in different

localities as a result of variations in the distance from the centre of mass of the Earth. Standard accepted value = 9.806 65 metres per second per second (32.174 ft per second per second). Symbol *g*.

accelerator (chem.) A substance that increases the rate of a *chemical reaction* (i.e. a *catalyst*), particularly in the manufacture of *vulcanized rubber*.

accelerator (phys.) A machine for increasing the *kinetic energy* of charged particles (e.g. *protons*, *electrons*, *nuclei*) by accelerating them in *electric fields*. In *electrostatic generators* (see also *Van de Graaff generator* and *tandem generator*) the acceleration is achieved directly by using a very high *potential difference*. In multiple accelerators a lower potential difference is used repeatedly to give the particle successive increments of energy. Multiple accelerators are classified as *linear accelerators* or *cyclic accelerators*. See *cyclotron*; *synchrotron*; *synchrocyclotron*; *betatron*; *bevatron*; *storage ring*.

accelerometer An instrument for measuring *acceleration*, especially the acceleration of an aircraft or *rocket*.

acceptor An imperfection in a *semiconductor* that causes *hole* conduction.

access time The time taken by a *computer store* to provide information to the *C.P.U.* The access time for high-speed stores is of the order of 1 *microsecond*; for *backing storage* it may be from 1 *millisecond* to some minutes.

accumulator Storage battery, secondary cell. A device for 'storing' *electricity*. An *electric current* is passed between two plates in a *liquid*; this causes chemical changes (due to *electrolysis*) in the plates and the liquid. When the changes are complete, the accumulator is charged. When the charged plates are joined externally by a *conductor* of electricity, the chemical changes are reversed, a current flows through the conductor till the reversal is complete, and the accumulator is discharged. In the common lead accumulator, the liquid is *sulphuric acid* of relative density 1.20 to 1.28, the positive plate when charged is *lead dioxide*, PbO_2 , and the negative plate is spongy lead. During discharge both plates tend to become lead sulphate, PbSO_4 , and the density of the acid solution falls. Discharge should not be continued beyond the point at which the relative density reaches 1.15, otherwise an insoluble sulphate of lead, not decomposed on re-charging, may be formed. When this occurs, the cell is said to be sulphated. Nickel-iron (Ni-Fe^*) accumulators in which the negative plate is iron and the positive plate is *nickel oxide* are also widely used. In these cells the liquid is a 20% solution of *potassium hydroxide*.

The increasing interest in all-electric cars has stimulated development of accumulators in recent years. One of the most promising devices is the zinc-air accumulator, which derives its *energy* from

ACETAL

the conversion of zinc to *zinc oxide*. The plates are made of zinc and oxygen is obtained from the air through a porous nickel *electrode*, the electrolyte is potassium hydroxide. The lead accumulator will provide some 8×10^4 joules per kg, whereas the zinc accumulator can provide 5 times this energy density. Even higher energy densities are obtainable from Na/S and Li/Cl accumulators but these require operating temperatures of 300-600°C. See also *fuel cells*.

acetal An *organic compound* of the general formula $RCH(OR')_2$, where R is hydrogen or an organic radical, and R' is an organic radical. Term is generally applied to $CH_3CH(OC_2H_5)_2$, a liquid, b.p. 104°C., used as a *solvent*, in perfumes, and in organic synthesis.

acetaldehyde Ethanal. CH_3CHO . A colourless *liquid* with a pungent fruity smell, b.p. 21°C. Formed by the *oxidation* of *ethanol*; further oxidation gives *acetic acid*. Used as an intermediate in the manufacture of many *organic compounds*.

acetaldol Aldol, 3-hydroxybutyraldehyde. $CH_3CH(OH)CH_2CHO$. A thick oily *liquid* formed by the *condensation* of *acetaldehyde*, b.p. 83°C. Used in the vulcanization of *rubber* and in perfumes.

acetamide Ethanamide. CH_3CONH_2 . A colourless crystalline substance, m.p. 81°C., odourless when pure. Used industrially as a *solvent*, etc.

acetanilide Antifebrin. $C_6H_5NHCOCH_3$. A white crystalline solid, m.p. 112°C. Used in the manufacture of dyes and drugs and as an *antipyretic*.

acetate a salt or an ester of *acetic acid*.

acetate plastics Plastics made from *cellulose acetate* (see also *rayon*).

acetic acid Ethanoic acid. CH_3COOH . The acid contained in *vinegar* (3 to 6%). A colourless corrosive *liquid* with a pungent smell; m.p. 16.6°C., b.p. 118.1°C. Solidifies at low temperatures to *glacial acetic acid*. Commercially obtained from *pyroligneous acid*, from *vinegar* made when *alcohol* is oxidized by the action of *bacteria*, and by the *oxidation* of *acetaldehyde*. Used in the manufacture of *cellulose acetate* and in other industries.

acetic anhydride Ethanoic anhydride. $(CH_3CO)_2O$. A colourless pungent *liquid*, the *anhydride* of *acetic acid*, b.p. 140°C., used in the manufacture of *plastics*.

acetic ether See *ethyl acetate*.

acetoin 3-hydroxy-2-butanone. $CH_3CH(OH)COCH_3$. A yellow *liquid*, b.p. 148°C., used in the manufacture of *flavours*.

acetyolysis The conversion of a group of atoms in an organic compound to an *acetyl* group by reacting the compound with *glacial acetic acid*.

acetone Propanone, dimethyl ketone. CH_3COCH_3 . A colourless inflammable *liquid* with a pleasant smell, b.p. 56.5°C., used as a *solvent* especially in the production of *cellulose acetate rayon*.

acetonitrile Methyl cyanide. CH_3CN . A colourless poisonous *liquid*, b.p. 82°C ., with an odour like *ether*. Used in organic synthesis and as a *solvent*.

acetophenone Acetylbenzene, phenyl methyl ketone. $\text{C}_6\text{H}_5\text{COCH}_3$. A colourless sweet-smelling *liquid*, b.p. 202.3°C ., used in the manufacture of perfume.

acetyl The *univalent organic radical*, $\text{CH}_3\text{CO}-$.

acetylation The introduction of an *acetyl group* into an organic compound.

acetylene Ethyne. C_2H_2 . A colourless poisonous inflammable gas; the first member of the *alkyne series*. It is made by the action of water on *calcium carbide*, CaC_2 , or by the action of an electric arc on other *hydrocarbons*. Used as a starting material for many *organic compounds*, and for *welding* on account of the high flame temperature (about 3300°C .) it produces when burnt in oxygen. (See *oxy-acetylene burner*).

acetylsalicylic acid See *aspirin*.

achromatic lens A *lens* free from *chromatic aberration*, giving an image free from coloured fringes. Consists of a pair of lenses, one of *crown glass*, the other of *flint glass*, the latter correcting the *dispersion* caused by the former.

acid A substance that liberates *hydrogen ions* in solution, reacts with a *base* to form a *salt* and water only, has a tendency to lose protons, and turns litmus red. Many acids are corrosive and have a sour taste. See also *strong acid*; *weak acid*; *Lewis acids and bases*.

acid amides See *amides*.

acid dyes A group of *dyes*, nearly all *salts of organic acids*; used chiefly for dyeing wool and natural silk from an acid dyebath.

acid halide Acyl halide. An organic compound with the general formula RCOX , where R is a hydrocarbon group and X is a *halogen atom*. They are obtained from carboxylic acids by replacing the hydroxyl group with a halogen atom. They are used in *halogenation*.

acidic Having the properties of an *acid*; the opposite of *alkaline*.

acidic hydrogen That portion of the hydrogen in an *acid* that is replaceable by *metals* to form *salts*.

acidimetry Determination of the amount of *acid* present in a *solution* by *titration*. See *volumetric analysis*.

acidolysis *Hydrolysis* by means of an *acid*.

acid radical A *molecule* of an *acid* without the *acidic hydrogen*. E.g., the *bivalent sulphate radical* $-\text{SO}_4$, from *sulphuric acid*, H_2SO_4 , is present in all sulphates.

acid salt An *acid* in which only a part of the *acid hydrogen* has been replaced by a *metal*. E.g. *sodium hydrogen carbonate*, NaHCO_3 .

acid value of a fat or oil. A measure of the free *fatty acid* present; the

ACLINIC LINE

number of *milligrams* of *potassium hydroxide* required to neutralize the free fatty acids in one gram of the substance.

acclinic line See *magnetic equator*.

acoustics The study of *sound*.

acoustic spectrum The range of frequencies occurring in the sound emitted by a source.

acoustoelectronics The study and use of devices in which *electronic signals* are converted by *transducers* into surface acoustic waves and passed through tiny solid strips. As acoustic signals are propagated some 10^5 times more slowly than *electromagnetic waves*, this technique enables *delay lines* to be constructed that can be up to 50 times lighter than pure electronic devices.

acre British unit of area. 4840 square yards. 4046.86 square metres.

acriflavine 3,6-diamino-10-methylacridinium chloride. $C_{14}H_{14}N_3Cl$. A yellow substance used as an *antiseptic*.

acrolein See *acrylaldehyde*.

acrylaldehyde Acrolein, acraldehyde. $CH_2:CH.CHO$. A colourless inflammable *liquid* with an irritating smell, b.p. $52.5^\circ C$., used in the synthesis of pharmaceutical products.

acrylic acid $CH_2:CH.COOH$. A corrosive *liquid*, m.p. $13^\circ C$., b.p. $141^\circ C$. Derivatives form the basis of the important *acrylic resins*.

acrylic resins Class of *plastics* obtained by the *polymerization* of derivatives of *acrylic acid*. They are transparent, colourless, and *thermoplastic*.

acrylonitrile Vinyl cyanide. $CH_2:CH.CN$. A colourless, highly poisonous, inflammable liquid, b.p. $78^\circ C$. Used in the manufacture of *plastics*, *synthetic rubbers*, and artificial textile fibres.

ACTH Adreno-cortico-tropic hormone. A *polypeptide hormone* secreted by the pituitary gland which controls the adrenal glands.

actinic radiation *Electromagnetic radiation* that can cause photochemical reactions, especially radiation that can be used as a source of illumination in photography. It includes *X-rays* and *infrared* and *ultraviolet* radiation, as well as light.

actinides Actinons. The name of the group of *elements* with *atomic numbers* from 89 (actinium) to 103; analogous to the *lanthanides*. See Appendix, Table 8.

actinium Ac. Element. A.W. 227. At. No. 89. A *radioactive* substance, half-life 21.6 years, m.p. $1050^\circ C$., b.p. $3200^\circ C$.

actinometer Any instrument that measures the intensity of *electromagnetic radiation*, especially one that is based on fluorescence or a photographic process.

actinon Actinium emanation. A gaseous *radioisotope* of radon, $^{219}_{86}Rn$, produced by the *disintegration* of actinium. It is now known as radon-219.

action The product of work and time. *Planck's constant* of action is measured in *SI units* of joule seconds.

activated alumina *Aluminium oxide* which has been dehydrated in such a way that a porous structure of high surface area is obtained.

Activated alumina has the power of adsorbing *water vapour* and certain gaseous *molecules*. Used for drying air and other gases.

activated carbon Active charcoal. Carbon, especially *charcoal*, which has been treated to remove *hydrocarbons* and to increase its powers of *adsorption*. Used in many industrial processes for recovering valuable materials out of gaseous mixtures, as a deodorant, and in *gas masks*.

activation (phys.) The process of inducing *radioactivity*.

activation analysis A sensitive analytical technique that can be used to detect the presence of several elements in a sample by first activating it, usually by neutron bombardment in a *nuclear reactor*, and then examining the gamma-ray spectrum of the decay products to detect characteristic emission lines.

activation energy The energy that must be supplied to a system in a *metastable state* to make a particular process occur. It is usually applied to systems on the atomic scale and the process may be an atomic reaction, such as fission, or an emission event.

active 1. Denoting an electronic component, such as a *transistor*, that is capable of amplification. **2.** See *satellites*, *artificial*. Compare *passive*.

active mass (chem.) In the Law of *Mass Action*, the active mass is taken to mean the *molecular concentration* of the substance under consideration.

activity (chem.) The effective *concentration* of a substance in a reacting system; this may differ from the true concentration owing to the action of forces between molecules or ions, etc. The activity coefficient is a multiplying factor for converting concentrations into activities; the activity coefficient for an *ideal solution* is 1.

activity (radioactive) **A.** The number of *disintegrations* of a *radioactive* material per second. The *SI unit* is the *becquerel*. See also *specific activity* and *curie*.

actomyosin A complex of two *proteins*, actin and myosin, that is the major constituent of muscle. The contraction of muscles is due to the shortening of actomyosin fibrils.

acute angle Angle of less than 90° .

acyclic Not cyclic; having an *open-chain* structure.

acyl The *univalent radical* $\text{RCO}-$, where R is an organic group; regarded as being derived from the corresponding *carboxylic acid*, RCOOH .

acylation The introduction of an *acyl group*, $-\text{RCO}$, into a compound.

adatom An adsorbed *atom*. See *adsorption*.

addition compound A chemical *compound* formed by the addition of an *atom* or group of atoms to a *molecule*. E.g. *phosgene*, COCl_2 , is an addition compound of *carbon monoxide*, CO, and chlorine, Cl_2 .

ADDITION REACTION

addition reaction A *chemical reaction* in which one or more of the *double bonds* in an *unsaturated compound* is converted to a single bond by the addition of another *atom* or group.

additive process The process of forming any *colour* by a mixture of red, green, and blue lights. The colours add together to form a new colour, the colour obtained depending on the proportions of each additive primary colour. Equal proportions give white light. Compare *subtractive process*.

adduct An *addition compound* formed by a reaction involving no *valence changes*.

adenine 6-aminopurine. $C_5H_3N_4NH_2$. A white crystalline *purine base*, m.p. $360-365^\circ C$., occurring in *nucleic acids*, which plays a part in the formulation of the *genetic code*. Also occurs in *adenosine triphosphate*.

adenosine triphosphate ATP. $C_{10}H_{12}N_5O_3H_4P_3O_9$. A *nucleotide* of importance in the transfer of *energy* within living *cells*. One of the phosphate groups can be readily transferred to other substances, in the presence of the appropriate *enzymes*, and with it goes a considerable amount of stored energy. It is as a result of the transfer of these phosphate groups that energy is made available in cells for chemical synthesis, muscle contraction, etc. ATP that has lost one phosphate group becomes the diphosphate (ADP). Adenosine is a *nucleoside* consisting of *adenine* and D-ribofuranose.

adhesion Sticking to a surface. The effect is produced by *forces* between *molecules*.

adhesives Substances used for sticking surfaces together; e.g. *glues*, *cements*, etc.

adiabatic Taking place without *heat* entering or leaving the system.

adiabatic demagnetization A method of attaining temperatures in the region of *absolute zero* by magnetizing a *paramagnetic salt*, such as potassium chrome alum or gadolinium sulphate, and allowing it to demagnetize adiabatically. During magnetization, between the poles of an electromagnet, the heat produced is removed by helium; during the adiabatic demagnetization cooling to very low temperatures takes place.

adipic acid $COOH(CH_2)_4COOH$. A white crystalline solid, m.p. $152^\circ C$., used in the synthesis of *nylon*.

admittance *Y*. The reciprocal of *impedance*.

adrenaline Epinephrine. 3, 4-dihydroxy- α -(methylaminomethyl) benzyl alcohol, $C_9H_{13}NO_3$. A *hormone* produced by the adrenal glands and synthetically. Used in medicine as a heart stimulant and to constrict blood vessels.

adsorbate The substance that is adsorbed on a surface. See *adsorption*.

adsorbent A substance that adsorbs. *Silica gel* and many porous or powdered materials are effective adsorbents by virtue of their large

specific surface in conjunction with their ability to form bonds with *adsorbates*. See *adsorption*.

adsorption The concentration of a substance on a surface; e.g. *molecules* of a *gas* or of a dissolved or suspended substance on the surface of a *solid*. In chemisorption a single layer of atoms or molecules of the adsorbed substance is held to the solid surface by *covalent bonds*. In physisorption, several layers of atoms or molecules are held by *Van der Waals forces*.

advanced gas-cooled reactor A.G.R. See *gas-cooled reactor*.

advection The process in which either *matter* or *energy* is transferred from one place to another by a horizontal stream of *gas*.

aelotropic See *anisotropic*.

aerial (U.S.A., antenna). That part of a *radio* system from which *energy* is transmitted into, or received from, *space* (or the *atmosphere*).

aerobic In the presence of free oxygen.

aerodynamics The study of the motion and control of solid bodies (e.g. aircraft, rockets, missiles, etc.) in *air*. The study of air or other *gases* in motion.

aerolites *Meteorites*, especially those consisting of stony material rather than iron.

aero metal A casting *alloy* consisting chiefly of aluminium, zinc, and copper.

aerosol A dispersion of *solid* or *liquid* particles in a *gas*; e.g. *smoke*.

aerospace The *Earth's atmosphere* and the *space* beyond.

aetiology (U.S.A., etiology) The science or philosophy of causation. Used in medicine to mean the science of the causes of disease.

affinity (chem.) Chemical attraction; the *force* binding *atoms* together.

afterburning 1. The *combustion* that results from the addition of *fuel* to the exhaust of a *jet engine* in order to increase *thrust* and reduce fuel consumption. 2. The irregular burning of residual *propellant* in a *rocket* motor when the main combustion has finished.

after-damp A poisonous mixture of *gases*, containing *carbon monoxide*, formed by the explosion of *fire-damp* (*methane*, CH_4) in coal-mines.

after-glow A glow sometimes observed high in the western sky after sunset. Caused by fine dust particles in the *upper atmosphere* scattering the *light* from the *Sun*.

after-heat *Heat* generated in a *nuclear reactor* after it has been shut down, by the *radioactive* substances formed in the *fuel elements*.

agar A *gelatin*-like material obtained from certain seaweeds; it is chemically related to the *carbohydrates*. A *solution* in hot water sets to a firm jelly, which is used as a base for *culture media* for growing *bacteria*.

agate A very hard natural form of *silica*, used for knife-edges of *balances*, for mortars for grinding hard materials, and in ornaments.

AGLYCONE

aglycone A non-sugar component of a *glycoside*.

agonic line A line of zero *magnetic declination*.

air See *atmosphere*.

air equivalent The thickness of a layer of air at *S.T.P.* that causes the same amount of absorption of nuclear radiation as the substance being considered.

air thermometer See *gas thermometer*.

alabaster Natural opaque form of *hydrated calcium sulphate*, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

alanine A colourless crystalline *soluble amino acid*. See Appendix, Table 5.

albedo 1. The ratio of the *radiant flux* falling on a surface to that reflected by it. 2. The probability that a *neutron* entering a material will be reflected back by that material through the surface by which it entered.

albumens, albumins A group of *soluble proteins* occurring in many animal *tissues* and *fluids*; e.g. egg-white (egg albumen), milk (lactalbunum), and *blood* (serum albumen).

albuminoids See *scleroproteins*.

alchemy The predecessor of scientific *chemistry*. An art by which its devotees sought, with the aid of a mixture of mysticism, *astrology*, practical chemistry, and quackery, to transmute *base metals* into gold, prolong human life, etc. Flourished from about A.D. 500 until the Middle Ages, when it gradually fell into disrepute.

alcoholates Metallic *salts* of *alcohols*, formed by replacement of *hydrogen* atoms in the *hydroxyl* groups of the latter by metals, e.g. sodium ethanolate (or sodium ethoxide), $\text{C}_2\text{H}_5\text{ONa}$.

alcoholometry The determination of the proportion of *ethanol* in spirits and other *solutions*; usually performed by measuring the relative density of the liquid at a standard *temperature* by a specially graduated *hydrometer*.

alcohols A class of *organic compounds* derived from the *hydrocarbons*, one or more *hydrogen atoms* in *molecules* of the latter being replaced by *hydroxyl groups*, $-\text{OH}$. E.g. *ethanol* (ordinary 'alcohol') is $\text{C}_2\text{H}_5\text{OH}$, theoretically derived from *ethane*, C_2H_6 . Alcohols that contain more than one *hydroxyl* group are called *polyhydric alcohols*. See also *diols* and *triols*.

aldehyde See *acetaldehyde*.

aldehydes A class of *organic compounds* of the type $\text{R} \cdot \text{CO} \cdot \text{H}$ where R is an *alkyl* or *aryl radical*.

aldol See *acetaldol*.

aldose A *monosaccharide* containing an aldehyde (*formyl*) group in the *molecule*.

algebra The branch of mathematics dealing with the properties of, and relationships between, quantities by means of general symbols.

algebraic sum The total of a number of quantities of the same kind, with due regard to sign. Thus the algebraic sum of 3, -5, and -2 is -4.

algin A loose term for *alginic acid* or its sodium salt.

alginic acid ($C_6H_8O_6$)_n. A complex *organic compound* related to the *carbohydrates*, found in certain seaweeds. Used for preparing *emulsions* and as a thickening agent in the food industry; its *salts*, the *alginates*, can be made into textile fibres which are *soluble* in *alkalis* and are used for special purposes.

algot Algorithmic language. A type of *computer language*, based on *Boolean algebra*, for expressing information in an algebraic notation.

algorithm Algorithm. A systematic mathematical procedure that enables a problem to be solved in a finite number of steps. Problems for which no algorithms exist require *heuristic* solutions.

alicyclic compound A type of *organic compound* that is essentially *aliphatic*, although it contains a *saturated* ring of carbon atoms.

alidade An instrument for measuring vertical heights and distances.

aliphatic compounds *Organic compounds* containing open chains of carbon atoms, in contradistinction to the closed rings of carbon atoms of the *aromatic compounds*. Comprise the *paraffins*, the *olefins* and the *acetylenes* as well as all their *derivatives* and *substitution products*.

aliquot part A divisor of a number or quantity that will give an *integer*. Thus 3 is an aliquot part of 6, but 5 is not.

alizarin 1:2 dihydroxyanthraquinone. $C_{14}H_6O_2(OH)_2$. An orange-red crystalline *solid*, m.p. 289°C. Colouring matter formerly extracted from the root of the madder plant, now made synthetically. Used in dyeing with the aid of *mordants*.

alkali A *soluble hydroxide* of a *metal*, particularly of one of the *alkali metals*; term is often applied to any substance that has an alkaline reaction (i.e. turns *litmus* blue and neutralizes *acids*) in solution. See also *base*.

alkali metals The *univalent metals* lithium, sodium, potassium, rubidium, and caesium, belonging to Group 1A of the *periodic table*.

alkalimetry The determination of the amount of *alkali* present in a *solution*, by *titration*. See *volumetric analysis*.

alkaline Having the properties of an *alkali*; the opposite of *acidic*.

alkaline earth metals The *bivalent* group of *metals* comprising beryllium, magnesium, calcium, strontium, barium, and radium, belonging to Group 2A of the *periodic table*.

alkaloids A group of *basic* organic substances of plant origin, containing at least one nitrogen atom in a ring structure in the *molecule*. Many have important physiological actions and are used in medicine. E.g. *codeine*, *cocaine*, *nicotine*, *quinine*, *morphine*.

ALKANES

alkanes A homologous series of saturated hydrocarbons having the general formula C_nH_{2n+2} . They are chemically inert, stable, and inflammable. The first four members of the series (*methane*, *ethane*, *propane*, *butane*) are gases at ordinary temperatures; the next eleven are liquids, and form the main constituents of *paraffin oil*; the higher members are solids. *Paraffin wax* consists mainly of higher alkanes.

alkanization The process of converting an unsaturated hydrocarbon into an *alkane*.

alkenes Olefins. A homologous series of unsaturated hydrocarbons having the general formula C_nH_{2n} .

alkoxy A general name for univalent organic radicals having the formula $RO-$, where R is an alkyl group.

alkyd resins See *glyptal resins*.

alkyl A general name for univalent saturated hydrocarbon radicals having the general formula C_nH_{2n+1} , derived from alkanes. E.g. *methyl*, CH_3- ; *ethyl*, C_2H_5- .

alkylarene An *arene* (e.g. *benzene*) with one or more hydrogen atoms in the molecule replaced by alkyl groups; e.g. *ethylbenzene*, $C_2H_5C_6H_5$.

alkylation The introduction of an alkyl group into a molecule; e.g. the addition of alkanes to alkenes.

alkynes A homologous series of unsaturated hydrocarbons having the general formula C_nH_{2n-2} and containing a triple bond between two of the carbon atoms in the molecule; e.g. *acetylene*.

allo- Prefix meaning 'other', used in chemistry to denote a variation from the standard or normal form.

allobar A mixture of the isotopes of an element that does not occur naturally.

allochromy The emission of radiation by a surface at a wavelength that differs from that of the incident radiation. See *fluorescence*.

allomerism A similarity in the crystalline structure of substances of different chemical composition.

allomorphism A variability in the crystalline structure of certain substances. Allomorphs are different crystalline forms of the same compound.

allotropes Allotropic forms. See *allotropy*.

allotropy The existence of a chemical element in two or more forms differing in physical properties but giving rise to identical chemical compounds. E.g. sulphur exists in a number of different allotropic forms.

allowed bands See *energy bands*.

alloxan $(CO)_4(NH)_2$. A white crystalline heterocyclic compound, m.p. $170^\circ C.$, derived from *uric acid* by treatment with dilute *nitric acid*. It destroys certain cells in the pancreas and is used to produce diabetes for experimental purposes.

- alloy** A composition of two or more *metals*; an alloy may be a *compound* of the metals, a *solid solution* of them, a heterogeneous *mixture*, or any combination of these. The term is sometimes extended to include non-metallic components; e.g. iron-carbon alloys.
- alluvial** Deposited by rivers.
- allyl alcohol** $\text{CH}_2\text{:CH.CH}_2\text{OH}$. A colourless pungent *liquid*, b.p. 96.5°C ., used in the manufacture of synthetic *resins* and pharmaceuticals.
- allyl group** The *univalent radical*, $\text{CH}_2\text{:CH.CH}_2\text{—}$, derived from *propylene*.
- allyl resins** Synthetic *resins* formed by the *polymerization* of chemical *compounds* containing the *allyl group*.
- Alnico*** A series of *alloys* based on iron and containing nickel, aluminium, cobalt, and copper. They are used to make permanent magnets.
- alpha decay** A form of *radioactive decay* in which a nucleus spontaneously emits an *alpha particle*.
- alpha-iron** Allotropic (see *allotropy*) form of pure iron that exists up to 900°C .
- alpha particle** Helium *nucleus*; i.e. a close combination of two *neutrons* and two *protons* (see *atom, structure of*), and therefore positively charged. Alpha particles are emitted from the *nuclei* of certain *radioactive elements*. See *radioactivity*.
- alpha rays** Streams of fast-moving *alpha particles*. Alpha rays produce intense *ionization* in *gases* through which they pass, are easily absorbed by *matter*, and produce *fluorescence* on a fluorescent screen.
- altazimuth** An instrument for the measurement of the *altitude* and *azimuth* of heavenly bodies.
- alternating current** a.c. A flow of *electricity* that, after reaching a maximum in one direction, decreases, finally reversing and reaching a maximum in the opposite direction, the *cycle* being repeated continuously. The number of such cycles per second is the *frequency*.
- alternator** A machine for producing electrical *alternating currents*.
- altimeter** An instrument used to measure height above sea-level. It usually consists of an *aneroid barometer* calibrated to read zero at sea-level and the height above sea-level in metres or feet.
- altitude** 1. Height. 2. The altitude of a heavenly body is its *angular distance* from the horizon on the vertical circle passing through the body, the *zenith*, and the *nadir*. See Fig. 2 under *azimuth*.
- alum** Potash alum. $\text{K}_2\text{SO}_4.\text{Al}_2(\text{SO}_4)_3.24\text{H}_2\text{O}$. Crystalline potassium aluminium sulphate. The *compound* occurs naturally and is used as a *mordant* in dyeing, for fireproofing, and other technical purposes.

ALUMINA

alumina See *aluminium oxide*, Al_2O_3 . Occurs naturally as *corundum* and *emery*, and in a *hydrated* form as *bauxite*. (See also *activated alumina*).

aluminium Al. Element. A.W. 26.9815. At. No. 13. A light white *metal*, r.d. 2.7, m.p. 659.70°C ., ductile and malleable, good *conductor* of electricity. Occurs widely in nature in *clays*, etc.; extracted mainly from *bauxite* by *electrolysis* of a molten mixture of purified *bauxite* and *cryolite*. The metal and its *alloys* are used for aircraft, cooking utensils, electrical apparatus, and for many other purposes where its light weight is an advantage.

aluminium acetate $\text{Al}(\text{CH}_3\text{COO})_3$. A white *soluble amorphous* powder, used as an *astringent* and *antiseptic*. Basic aluminium acetate, $\text{AlOH}(\text{CH}_3\text{COO})_2 \cdot x\text{H}_2\text{O}$, a white crystalline powder, is used as a waterproofing and fireproofing compound in the textile industry.

aluminium brass Brass containing small amounts of aluminium.

aluminium bronze An *alloy* of copper containing 4%-13% aluminium.

aluminium hydroxide $\text{Al}(\text{OH})_3$. A white *insoluble amphoteric* powder used in the manufacture of *glass* and *ceramics*, and as an *antacid* in medicine.

aluminium oxide Alumina. Al_2O_3 . A white crystalline substance, m.p. 2015°C ., used in *cement*, as a *refractory*, and in the manufacture of aluminium. See also *activated alumina*.

aluminium sulphate $\text{Al}_2(\text{SO}_4)_3$. A white crystalline *soluble* substance, used in *purifying water*, in the manufacture of *paper* and in *fire extinguishers*.

aluminosilicates A large class of *minerals*, both natural and synthetic, containing aluminium and silicon combined with oxygen in their structure. It includes *clays*, *zeolites*, *micas*, and many other important mineral materials.

aluminothermic reduction High-temperature *reduction* of metal oxides to the corresponding metals by the *thermite* method.

alums Double *salts* of the general formula



where M is a *univalent metal* such as sodium, potassium, or ammonium, and R is a *tervalent metal* such as aluminium or chromium.

alum-stone See *alunite*.

alunite Alum-stone. A natural *compound* of potassium and *aluminium sulphate* and *aluminium hydroxide*, $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 4\text{Al}(\text{OH})_3$. Used as a source of *alum*.

amalgam An *alloy* of mercury.

amalgamation process for gold. Gold-bearing rock or sand, after crushing, is treated with mercury, which forms an *amalgam* on the surface of the gold. The amalgamated particles are allowed to stick to amalgamated copper plates, the rest of the ore being washed

away; they are then removed, the mercury is distilled off in iron *retorts*, and the remaining gold purified by *cupellation*.

amatol An explosive mixture of 80% *ammonium nitrate* and 20% *T.N.T.*

amber Succinite. A fossil *resin*, derived from an extinct species of pine. Obtained from mines in East Prussia, and found on seashores. A yellow to brown solid, which contains *succinic acid*, used for ornamental purposes.

amberggris A grey or black waxy material that occurs (probably as the result of disease) in the intestines of the sperm whale. Used in perfumery.

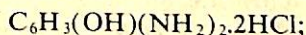
americium Am. *Transuranic element*. At. No. 95. *Radioactive*. A member of the *actinide* series. Most stable *isotope*, $^{243}_{95}\text{Am}$, has half-life of 8.8×10^3 years. R.d. 13.7, m.p. 995°C .

amethyst A violet variety of *quartz*; impure crystalline *silica*, SiO_2 .

amidases *Enzymes* that control *hydrolysis* of *amides*.

amides A group of *organic compounds* formed by replacing hydrogen atoms of *ammonia*, NH_3 , by *acyl radicals*. E.g. *acetamide*, CH_3CONH_2 . The general formula is RCONH_2 , where $-\text{CONH}_2$ is the amide group.

Amidol* 2:4-diaminophenol dihydrochloride,



used in *photography* as a developer.

aminases *Enzymes* that *catalyze* the *hydrolysis* of *amines*.

amination The conversion of an *aldehyde* or *ketone* into an *amine*, by reacting them with hydrogen and ammonia in the presence of a catalyst.

amines Compounds formed by replacing hydrogen atoms of *ammonia*, NH_3 , by organic *radicals*. Classified into primary amines of the type NH_2R ; secondary, NHR_2 ; and tertiary, NR_3 . See also *quaternary ammonium compounds*.

amino acid A *carboxylic acid* that contains the *amino group* $-\text{NH}_2$. These acids are the units that link together into *polypeptide* chains to form *proteins*; they are therefore of fundamental importance to life. Some twenty different amino acids occur in nature, all of which have the general formula: $\text{R}-\text{CH}-\text{NH}_2-\text{COOH}$. See Appendix, Table 5. 'Essential' amino acids are those that an *organism* is unable to synthesize and therefore has to obtain from its environment. There are eight 'essential' amino acids for man.

amino group The *univalent* group $-\text{NH}_2$.

aminoplastic resins Synthetic *resins* derived from the reaction of *urea*, *melamine*, or allied amino compounds with *aldehydes*. They form the basis of *thermosetting* moulding materials.

ammeter An instrument for the measurement of *electric current*. In moving iron ammeters, a strip of soft iron is caused to move in the

AMMINES

magnetic field set up by the current flowing through a coil; for the measurement of *direct current*, the more accurate moving coil instruments contain a permanent *magnet* between the poles of which is pivoted a coil carrying the current to be measured. In each type of instrument a pointer attached to the moving portion moves over a scale graduated in *amperes*.

ammines *Coordination compounds* containing *ammonia* molecules as *ligands*; *complex compounds* formed by ammonia with *salts* or *bases*.

ammonal A *mixture* of *ammonium nitrate*, NH_4NO_3 , and aluminium. Used as an *explosive*.

ammonia NH_3 . A pungent-smelling very *soluble* gas, giving an *alkaline solution* containing *ammonium hydroxide*, NH_4OH . Obtained synthetically from atmospheric nitrogen (see *Haber process*) and as a by-product of coal-gas manufacture. Used as a *refrigerant*, and for the manufacture of *explosives* and *fertilizers*.

ammonia clock An atomic clock based on the vibrational frequency with which the nitrogen atom in the *ammonia* molecule passes through the plane of the three hydrogen atoms and back again. The vibration has a frequency of 23 870 *hertz* and a *quartz crystal* is used to supply ammonia gas with energy at this frequency. Because the ammonia will only absorb energy at this frequency, the ammonia can be used to regulate the frequency of the quartz oscillator, through a feedback circuit.

ammonium acetate $\text{CH}_3\text{COONH}_4$. A white *deliquescent* solid, m.p. 114°C ., used as a meat preservative and in the manufacture of *dyes*.

ammonium chloride Sal ammoniac. NH_4Cl . A white *soluble* crystalline salt, used in *dry cells* and *Leclanché cells*.

ammonium hydroxide NH_4OH . A *compound* presumed to exist in *aqueous solutions* of *ammonia*; the name is often applied to the *solution*.

ammonium nitrate NH_4NO_3 . A white *soluble* crystalline salt, m.p. 169.6°C ., that decomposes on heating to form *nitrous oxide*, N_2O , and water. Used in *explosives*, e.g. *ammonal*, *amatol*.

ammonium radical NH_4^- . A *univalent radical* that has not been obtained free, but in *compounds* behaves similarly to an *alkali metal*, giving rise to *ammonium salts*.

ammonium sodium hydrogen orthophosphate Microcosmic salt. $\text{NH}_4\text{NaHPO}_4 \cdot 4\text{H}_2\text{O}$. A white crystalline *soluble* salt, used as a *flux*.

ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$. A white *soluble* crystalline salt, obtained as a by-product of coal-gas manufacture, used as a *fertilizer*.

ammonium thiocyanate NH_4SCN . A colourless *soluble* crystalline substance, m.p. 149.6°C ., used as a herbicide and in the textile industry.

ammonolysis A chemical reaction in which one group of an organic compound is converted to an *amine* group, by reacting the compound with ammonia.

amorphous Non-crystalline; having no definite form or shape.

amount of substance *n*. A basic physical quantity that is proportional to the number of specified particles of a substance. The specified particle may be an *atom*, *molecule*, *ion*, *radical*, *electron*, *photon*, etc., or any specified group of such particles. The constant of proportionality, *Avogadro's constant*, is the same for all substances. The basic *SI unit* of amount of substance is the *mole*.

ampere A unit of *electric current* approximately equivalent to the flow of 6×10^{18} *electrons* per second. The absolute ampere, which is one-tenth of an abampere (see *ab-*), is equal to 1.000 165 International amperes. The International ampere was originally defined as the unvarying current that when passed through a solution of *silver nitrate*, deposits silver at the rate of 0.001 118 00 gram per second. The ampere was redefined in 1948 as the intensity of a constant current that, if maintained in two parallel, rectilinear conductors of infinite length, of negligible circular section and placed at a distance of one *metre* from one another in vacuo, will produce between the conductors a *force* equal to 2×10^{-7} *newton* per *metre* of length. The ampere so defined is the basic *SI unit* of current. Symbol *A*. Named after A. M. Ampère (1775-1836).

ampere-hour The practical unit of quantity of *electricity*; the amount of electricity flowing per hour through a *conductor* when the current in it is one *ampere*. 3600 *coulombs*.

Ampere's law The strength of the *magnetic field* induced by a *current* flowing through a *conductor* is, at any point, directly proportional to the *product* of the current and the length of the conductor and inversely proportional to the *square* of the distance between the point and the conductor. The direction of the field is perpendicular to the *plane* joining the point and the conductor.

ampere-turns A measure of *magnetomotive force*. The product of the number of turns in a coil and the current in *amperes* which flows through it.

amphetamine $C_6H_5CH_2CHNH_2CH_3$. A *drug*, used in the form of the *sulphate*, that stimulates the central nervous system in cases of depression. Also known under the trade name, Benzedrine*.

amphiboles A group of complex *silicate minerals* that includes *hornblende* and *asbestos*.

amphichroic Amphichromatic. Giving one colour on reaction with an *acid* and another colour on reaction with a *base*.

amphiprotic Capable both of accepting and of yielding *protons* in solution; *amphoteric*.

ampholyte An *amphoteric electrolyte*.

AMPHOTERIC

amphoteric Chemically reacting as *acidic* to strong *bases* and as *basic* towards strong *acids*. E.g. the amphoteric *oxide*, *zinc oxide*, gives rise to *zinc salts* of strong *acids* and *zincates* of the *alkali metals*.

amplifier An *electronic* device that increases the strength of a signal fed into it, by obtaining *power* from a source other than the input signal.

amplitude (phys.) If any quantity is varying in an oscillatory manner about an equilibrium value, the maximum departure from that equilibrium value is called the amplitude; e.g. in the case of a *pendulum* the amplitude is half the length of the swing. For a wave motion, e.g. *electromagnetic waves* or *sound waves*, the amplitude of the wave determines the amount of *energy* carried by the wave.

amplitude modulation One of the principal methods of transmitting information by *radio waves*. The *amplitude* of a *carrier wave* is modulated (see *modulation*) in accordance with the *frequency* of the signal to be transmitted.

AMU See *atomic mass units*.

amyl *Pentyl*. The *univalent radical* $C_5H_{11}-$.

amyl acetate *Pentyl acetate*, *banana oil*. $CH_3COOC_5H_{11}$. An *ester* of *amyl alcohol* and *acetic acid*. A colourless liquid, b.p. $148^\circ C.$, with an odour of pear drops. Used as a *solvent*, a *flavour*, and in *perfumes*.

amyl alcohol $C_5H_{11}OH$. A colourless *liquid* with a characteristic smell. It exists in several isomeric forms (see *isomerism*). Commercial *amyl alcohol* consists mainly of *iso-amyl alcohol*,



b.p. $131.4^\circ C.$, and is obtained from *fusel oil*. Used as a *solvent*.

amylases A group of *enzymes* capable of splitting *starch* and *glycogen* into *sugars*. Found in many plants and animals (e.g. the *pancreatic juices* of mammals).

amyopectin The principal component (about 80%) of most cereal *starches* (see *starch*). A *polysaccharide* whose molecules consist of long cross-linked chains of *glucose* units. It is insoluble in water. Compare *amylose*.

amylose A water-soluble component (about 20%) of most cereal *starches* (see *starch*). A *polysaccharide* whose molecules consist of long unbranched chains of *glucose* units, structurally related to *cellulose*. Compare *amyopectin*.

amylum See *starch*.

anabolism Part of *metabolism*, comprising the building-up of complex substances from simpler material, with absorption and storage of *energy*.

anaerobic In the absence of free oxygen.

anaesthetic A substance used in medicine to produce insensibility or loss of feeling.

- analgesic** A substance used in medicine to relieve pain.
- analog computer** A *computer* in which numerical magnitudes are represented by physical quantities such as *electric current*, *voltage*, or *resistance*. See also *digital computer*.
- analysis** (chem.) The process of determining the composition of a substance. See *colorimetric*, *gravimetric*, *qualitative*, *quantitative*, *spectrographic*, and *volumetric analysis*.
- analytical geometry** Coordinate geometry. A form of *geometry* based upon the use of *coordinates* to define positions in *space*. See *Cartesian coordinates* and *polar coordinates*.
- anastigmatic lens** A *lens* designed to correct *astigmatism*.
- anatase** Crystalline form of natural *titanium dioxide*, TiO_2 .
- androgen** A *steroid*, or other substance, that promotes male characteristics in vertebrates; e.g. *testosterone*.
- anechoic** Having a low degree of reverberation.
- anemo-** Prefix denoting the wind.
- anemometer** Instrument for measuring the speed of wind or any other moving gas.
- aneroid** Without liquid. The aneroid *barometer* is an instrument for measuring atmospheric *pressure*; it consists of an exhausted metal box with a thin corrugated metal lid. Variations in atmospheric pressure cause changes in the displacement of the lid; this displacement is magnified and made to actuate a pointer moving over a scale by means of a system of delicate levers.
- anethole** $\text{CH}_3\text{CH}:\text{CHC}_6\text{H}_4\text{OCH}_3$. A white crystalline powder, m.p. 22.5°C ., used in perfumes, flavouring, and in medicine.
- aneurine** See *thiamine*.
- angle** The space between two intersecting lines or *planes*. Measured in *degrees* or in *radians* (see *circular measure*).
- Ångström unit** Å.U., 10^{-10} *metre*. A unit of length, formerly used for measurement of *wavelengths* of *light* and intra-molecular distances. $10 \text{ Å.U.} = 1 \text{ nanometre}$.
- angular acceleration** The rate of change of *angular velocity*.
- angular displacement** The *angle* through which a point, line, or body has been rotated in a specified direction, about a specified *axis*.
- angular distance** The distance between two bodies, measured in terms of the *angle* subtended by them at the point of observation; used in *astronomy*.
- angular frequency** The *frequency* of a periodic process expressed in *radians per second*; equal to 2π times the number of *cycles per second*.
- angular momentum** The product of *moment of inertia* and *angular velocity*. For the angular momentum of *elementary particles* see *spin*.
- angular velocity** Rate of motion through an *angle* about an *axis*. Measured in *degrees*, *radians*, or revolutions per unit time.

ANHYDRIDE

anhydride The anhydride of a substance is that which, when chemically combined with *water*, gives the substance. A *basic* anhydride is the *oxide* of a *metal* and forms a *base* with *water* (e.g. $\text{Na}_2\text{O} + \text{H}_2\text{O} = 2\text{NaOH}$): an *acidic* anhydride is the *oxide* of a non-metal and forms an *acid* with *water* (e.g. $\text{SO}_3 + \text{H}_2\text{O} = \text{H}_2\text{SO}_4$). In organic chemistry an anhydride is formed by the action of *dehydrating agents* on *carboxylic acids*, giving the anhydride group $-\text{CO}-\text{O}-\text{CO}-$: e.g. two molecules of *acetic acid* (CH_3COOH) on *dehydration* yield one molecule of *acetic anhydride* ($\text{CH}_3\text{CO}-\text{O}-\text{COCH}_3$).

anhydrite A naturally occurring form of *calcium sulphate*, CaSO_4 .

anhydrous Without *water*; often applied to *salts* without *water of crystallization*.

anilide An *organic compound* analogous to an *amide* but derived from an *aromatic amine*, especially *aniline*.

aniline Phenylamine, aminobenzene. $\text{C}_6\text{H}_5\text{NH}_2$. A colourless oily *liquid* with a peculiar smell, b.p. 184.4°C . Made by the reduction of *nitrobenzene*, $\text{C}_6\text{H}_5\text{NO}_2$, which is obtained from *benzene* extracted from *coal-tar*. Used in the manufacture of many important products, including *dyes*, *drugs*, and *plastics*.

aniline dyes *Dyes* prepared or chemically derived from *aniline*.

anilino The *univalent radical* $\text{C}_6\text{H}_5\text{NH}-$.

animal charcoal Bone black, bone char. Material containing 10% carbon and 90% inorganic matter, chiefly *calcium phosphate*, $\text{Ca}_3(\text{PO}_4)_2$, obtained by charring bones and other animal substances. Used as a decolorizing agent.

animal starch See *glycogen*.

anion A negatively charged *ion*; an ion that is attracted towards the *anode* in *electrolysis*.

anisaldehyde Aubepine. A colourless oily *liquid*, the *para*- form of $\text{CH}_3\text{OC}_6\text{H}_4\text{CHO}$. B.p. 247°C ., used in cosmetics and perfumes.

anisole Methyl phenyl ether. $\text{CH}_3\text{OC}_6\text{H}_5$. A colourless *liquid* with an aromatic odour, b.p. 155.4°C ., used in perfumes and as a *vermicide*.

anisometric Not *isometric*. Applied to *crystals* that have axes of different lengths.

anisotropic Aelotropic. Possessing different physical properties in different directions; e.g. certain *crystals* have a different *refractive index* in different directions.

anisyl alcohol Anisalcohol. $\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{OH}$. A colourless *liquid*, b.p. 258.8°C ., used in perfumes.

annealing Very slow regulated cooling, especially of *metals*, to relieve *strains* set up during heating or other treatment.

annihilation radiation The *electromagnetic radiation* that results from the collision, and subsequent annihilation, of a particle and its corresponding *anti-particle*. In the collision between an *electron* and a *positron* the annihilation radiation usually consists of two

photons of γ -radiation emitted in opposite directions. The *energy* of the annihilation radiation is derived from the *mass* of the annihilated particles according to the *mass-energy equation*.

annual variation A very small regular variation that the *magnetic declination* undergoes in the course of a year.

annular Ringed. An annular space is the space between an inner and outer ring.

annular eclipse An *eclipse* of the *Sun* in which a ring of its surface is visible surrounding the darkened *Moon*.

anode Positive *electrode*. See *electrolysis* and *thermionic valve*.

anodizing Producing an *oxide* coating on a metallic surface by making it the *anode* in an electrolytic bath (see *electrolysis*).

anolyte The *electrolyte* near the *anode* during *electrolysis*.

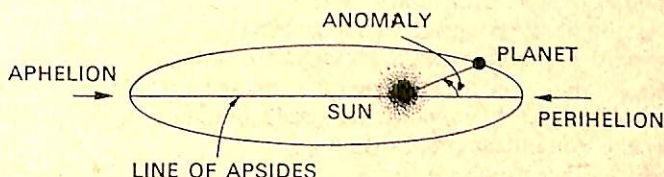


Figure 1.

anomaly (astr.) A term used to describe the position of a *planet* in its *orbit*. The 'true anomaly' is the *angle* between the *perihelion*, the *Sun*, and the planet, in the direction of the planet's motion. See Fig. 1. The 'mean anomaly' is the angle between the perihelion, the Sun and a fictitious planet having the same *period* as the real planet, but assumed to be moving with a constant *velocity*.

antacid A pharmaceutical term for a substance that counteracts stomach acidity.

antenna See *aerial*.

anthracene $C_6H_4(CH)_2C_6H_4$. A white crystalline polycyclic *hydrocarbon* with a blue *fluorescence*; often yellowish due to impurities. M.p. $217^\circ C$. Obtained from *coal-tar*; used in the manufacture of *dyes*.

anthracite A hard form of *coal*, containing more carbon and far less *hydrocarbons* than other forms. Probably the oldest form of coal.

anthraquinone $C_6H_4(CO_2)_2C_6H_4$. A yellow *insoluble* powder, derived from *anthracene* and used as an *intermediate* in the manufacture of an important class of *vat dyes*.

anti- Prefix denoting opposite, against. E.g. *antichlor*.

antibiotics Chemical substances produced by *microorganisms* such as moulds and *bacteria*, which are capable of destroying bacteria or preventing their growth. Numerous antibiotics have been discovered,

ANTIBODY

the first of which was *penicillin*. See *Aureomycin*; *streptomycin*; *Chloromycetin*; *erythromycin*; *Terramycin*; *nystatin*.

antibody A *protein* produced by animal plasma cells (of the reticuloendothelial system) as a result of the presence of an *antigen*. Specific antigens stimulate the formation of specific antibodies. The function of the antibodies is to combine chemically with antigens and thereby to render them harmless to the *organism* that they are invading. As parasitic *organisms* and *viruses* produce, or are associated with, specific antigens, the consequent antibody formation provides a defence mechanism against these invading parasites. Once produced, antibodies persist in the bloodstream and therefore confer enduring immunity against the infecting organisms of antigens. Immunity to disease by inoculation is brought about by injecting antigens into the bloodstream with the object of stimulating the formation of antibodies. See also *vaccine*.

antichlor A substance used to remove chlorine from materials after *bleaching*. E.g. *sodium thiosulphate*, $\text{Na}_2\text{S}_2\text{O}_3$.

antidote A remedy for a particular poison, which generally acts chemically upon the poison, thus neutralizing it, making it *insoluble*, or otherwise rendering it harmless.

antifebrin See *acetanilide*.

antiferromagnetism A type of *magnetism* that occurs in certain inorganic compounds, such as MnO , MnS , and FeO . These materials have a low *susceptibility*, which increases with temperature up to the Néel temperature, above which the susceptibility falls and the material becomes *paramagnetic*. The phenomenon arises in substances in which interaction between neighbouring atoms leads to an *antiparallel* arrangement of magnetic *dipole moments*.

anti-freeze A substance added to water in radiators of motor-car engines in order to lower the *freezing point* of the water. *Ethanedial* (ethylene glycol), $\text{CH}_2\text{OH}.\text{CH}_2\text{OH}$, is frequently used.

antigen A *protein* or *carbohydrate* that is foreign to an *organism* and capable of stimulating the formation of *antibodies*.

antihistamines A group of *drugs* that counteract the effect of *histamine* in the body and are therefore used in the treatment of allergic diseases.

antilogarithm Antilog. The number represented by a *logarithm*.

anti-matter Hypothetical *matter* composed of *anti-particles*. Anti-hydrogen, for example, would consist of an anti-proton and an orbital *positron*. While theoretically possible, the existence of anti-matter in the *Universe* has never been detected. Contact between anti-matter and matter would result in the annihilation of both with the production of *annihilation radiation*.

antimony Sb. (Stibium.) Element. A.W. 121.75. At. No. 51. A brittle crystalline silvery-white *metal*, r.d. 6.69, m.p. 630°C ., expands on solidifying. Occurs as the *element*, *oxide*, and *sulphide* (*stibnite*,

- Sb_2S_3). Extracted from its ores by roasting the ore and reducing with carbon. Used in *type metal* and other *alloys*.
- antimony hydride** See *stibine*.
- antimony pentasulphide** Sb_2S_5 . A yellow *insoluble* powder, used as a *pigment* and in the *vulcanization of rubber*.
- antimony potassium tartrate** Tartar emetic. Potassium antimonyl tartrate. $2\text{K}(\text{SbO})\text{C}_4\text{H}_4\text{O}_6 \cdot \text{H}_2\text{O}$. A white *soluble* poisonous powder, used as an emetic and as a *mordant*.
- antimony sulphate** $\text{Sb}_2(\text{SO}_4)_3$. A white crystalline *insoluble* solid, used in *explosives*.
- antimony trisulphide** Stibnite. Sb_2S_3 . A black or red *insoluble* crystalline solid, m.p. 550°C ., used as a *pigment* and also in fireworks and *matches*.
- antinodes** Points of maximum displacement in a series of *standing waves*. Two similar and equal *wave motions* travelling with equal *velocities* in opposite directions along a straight line give rise to antinodes and *nodes* alternately along the line. The antinodes are separated from their adjacent nodes by a distance corresponding to a quarter of the *wavelength* of the wave motions.
- antioxidants** Agents added to certain materials, such as *rubber*, *plastics*, *paints*, and *oils*, to prevent the harmful effects to the materials of oxidation.
- antiparallel vectors** Having parallel lines of action but acting in opposite directions.
- anti-particle** Every *elementary particle* has a corresponding real or hypothetical anti-particle, of equal *mass* but opposite *electric charge*, with which annihilation can take place. The anti-particle of the *electron* is the *positron*. Anti-*neutrons*, anti-*neutrinos*, and anti-*protons*, amongst others, have been detected. The anti-neutron has the same mass and *spin* as a neutron, but opposite *magnetic moment*.
- antipyretic** Febrifuge. A substance used medically to lower the body *temperature*.
- antiseptic** Preventing the growth of *bacteria*.
- antisquawk agents** Substances added to lubricating oils to suppress noise in the operation of automatic clutches, etc.
- apatite** Natural *phosphate* and *fluoride* of calcium, $\text{CaF}_2 \cdot 3\text{Ca}_3(\text{PO}_4)_2$. Used in the manufacture of *fertilizers*.
- aperture** Opening; in optical instruments, the size of the opening admitting *light* to the instrument. In spherical *mirrors* or *lenses*, the diameter of the reflecting or refracting surface.
- aperture synthesis** The use of two small *aerials* in a *radio telescope* to synthesize a large *aperture*. This principle can be used both with *parabolic reflectors* and *radio interferometers*, but it usually best employed in conjunction with an *unfilled aperture*.

APHELION

aphelion The time, or point, in a *planet's orbit* when it is furthest from the *Sun*. The opposite of *perihelion*. See Fig. 1 under *anomaly*.

aplanatic If any reflecting or refracting surface produces a point image at *B* of a point object at *A* irrespective of the angle at which the rays fall on the surface from *A*, then that surface is said to be aplanatic with respect to *A* and *B*.

apocynthion The time, or point, of greatest distance of a *satellite* in lunar orbit from the *Moon's* surface. The opposite of *pericynthion*.

apogee The *Moon* or any other Earth *satellite* is said to be in apogee when it is at its greatest distance from the Earth. The opposite of *perigee*.

apomorphine $C_{17}H_{17}NO_2$. A crystalline *alkaloid*, derived from *morphine*, used in the form of its hydrochloride as an emetic.

apothecaries' fluid measure

1 minim	=	0.0591 cc (about 1 drop)
60 minims	=	1 fluid drachm = 3.55 cc
8 fl dr	=	1 fluid ounce = 28.41 cc
20 fl oz	=	1 pint = 568 cc

These measures are now largely replaced by *metric units*.

apothecaries' weights See *Troy weight*.

apothem A *perpendicular* from the centre of a regular *polygon* to one of its sides.

apparent depth The depth of a *liquid* viewed from above appears to be less than the true depth, owing to the *refraction of light*. The ratio of the true depth to the apparent depth is equal to the *refractive index* of the liquid.

apparent expansion Relative expansion of a *liquid*. See *expansion of liquids*.

Appleton layer See *ionosphere*.

apsis (plural *apsides*). One of the extremities of the major *axis* of the orbit of a *planet* or *comet*. See *perihelion* and *aphelion*. The 'line of apsides' joins one apsis to the other. See Fig. 1 under *anomaly*.

aq (chem.) Symbol denoting *water*; e.g. $H_2SO_4.aq.$ is *aqueous sulphuric acid*.

aqua fortis Concentrated *nitric acid*, HNO_3 .

aquamarine Bluish form of *beryl*.

aqua regia Mixture of concentrated *nitric* and *hydrochloric acids* (1 to 4 by volume). Highly corrosive *liquid* which dissolves gold and attacks many substances unaffected by other reagents. Turns orange-yellow owing to the formation of nitrosyl chloride, $NOCl$, and free chlorine.

aqueous Watery. Usually applied to *solutions*, indicating that *water* is the *solvent*.

arabinose Pectinose. $C_5H_{10}O_5$. A white *soluble* crystalline solid, m.p. $164.5^\circ C.$, obtained from *gums* or synthetically from *glucose*, used as a *culture medium* in *bacteriology*.

arachidic acid Arachic acid. $\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$. A white crystalline insoluble solid, m.p. 76.3°C ., obtained from peanut oil and used in lubricants, plastics, and waxes.

arc, electric A highly luminous discharge, accompanied by a *temperature* of over 3000°C .; produced when an *electric current* flows through a gap between two *electrodes*, the current being carried by the *vapour* of the electrode; e.g. the common carbon arc is formed between two carbon rods, and constitutes a very bright source of *light*. In the same way metallic arcs are formed between two similar metallic surfaces.

Archimedes' principle The apparent loss in *weight* of a body totally or partially immersed in a *liquid* is equal to the weight of the liquid displaced. See *buoyancy*. Named after the Greek mathematician (287-212 B.C.).

arc lamp A technical application of the electric arc to produce a very bright *light*. The *carbon arc lamp* consists of an electric arc between two carbon *electrodes*, with suitable automatic mechanism for striking the arc and drawing the carbons closer together as they are vaporized away. The mercury arc lamp is important for laboratory use.

arc of circle See *circle*.

arc sin, tan, cos See *inverse trigonometrical functions*.

are Metric unit of *area* 1 square dekametre, 100 square *metres*, 119.60 square yards.

area Measure of surface; measured in 'square' units of length, e.g. square *metres*.

area, British units

1 square inch	= 6.4516 square cm
144 sq ins	= 1 sq foot = 929 sq cm
9 sq ft	= 1 sq yard
$30\frac{1}{4}$ sq yds	= 1 sq pole
40 sq pls	= 1 rood
484 sq yds	= 1 sq chain
4 roods	= 4840 sq yds = 1 acre
640 acres	= 1 sq mile

See also Appendix, Table 1.

area, metric units

1 sq centimetre	= 0.155 sq inch
10 000 sq cm	= 1 centare = 1 sq metre
100 sq m	= 1 are
100 ares	= 1 hectare = 2.47105 acres
100 hectares	= 1 sq kilometre

See also Appendix, Table 1.

arene An aromatic hydrocarbon.

Argand diagram 1. The representation of a *complex number*, $z = x + iy$, as the point (x, y) in *Cartesian coordinates*, using the

ARGENTIFEROUS

horizontal (x -axis) to represent the real part of the number and the vertical (y -axis) to represent the imaginary part of the number. In *polar coordinates*, the point is represented by (r, θ) , where θ is the argument of the complex number and r is its modulus. 2. A *vector diagram* showing the magnitude and phase angle of any vector with respect to another. Named after J. R. Argand (1768-1822).

argentiferous Silver-bearing.

argentite Silver glance. Natural silver sulphide, Ag_2S . An important ore of silver.

arginine An essential *amino acid*. See Appendix, Table 5.

argol Tartar. A reddish-brown crystalline deposit consisting mainly of *potassium hydrogen tartrate*, which separates in wine-vats.

argon Ar. Element. A.W. 39.948. At. No. 18. An *inert gas* that occurs in the air (0.9%). Used for filling electric lamps and in fluorescent tubes at a pressure of about 3 mm of mercury (400 N m^{-2}). See also *potassium-argon dating*.

argument (math.) 1. An independent *variable* that forms part of a *function*. 2. See *Argand diagram*.

arithmetical progression *Series* of quantities in which each term differs from the preceding by a constant common difference. For an A.P. in which the first term is a , the common difference d , the number of terms n , the last term L , and the sum of n terms S ,

$$S = n[2a + (n-1)d]/2$$

$$S = n(a + L)/2$$

$$L = a + (n-1)d.$$

armature The coil or coils, usually rotating, of a *dynamo* or *electric motor*. Also more widely used as any part of an electric apparatus or machine in which a *voltage* is induced by a *magnetic field*, e.g. in gramophone pick-ups, electromagnetic loudspeakers, *relays*, etc.

aromatic (chem.) The original concept of aromatic compounds as derivatives of *benzene* has been extended to certain other organic compounds. See *aromaticity*.

aromaticity The degree to which a cyclic organic compound or *ion* with *double bonds* in the ring exhibits the high stability and specific reactivity (i.e. tendency to undergo substitution rather than addition reactions) characteristic of *benzene* and its derivatives. It is exhibited to a high degree by such compounds as *pyridine*, *quinoline*, and *thiophene*.

arsenate A *salt* or *ester* of *arsenic acid*.

arsenic As. Element. A.W. 74.9216. At. No. 33. Exists in three *allotropic* forms; ordinary grey metallic arsenic, r.d. 5.727, black arsenic, r.d. 4.5, and yellow arsenic, r.d. 2.0. Occurs combined with sulphur as *realgar*, As_2S_2 , *orpiment*, As_2S_3 ; with oxygen as *white arsenic*, As_2O_3 ; with some *metals* and as the *element*. Metallic

- arsenic is used in *semiconductors* and in *alloys*. *Compounds* are very poisonous and are used in medicine and for destroying pests.
- arsenic acid** $\text{H}_3\text{AsO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$. A white *soluble* crystalline powder, m.p. 35.5°C ., used in the manufacture of *arsenates*.
- arsenical pyrites** See *mispickel*.
- arsenic disulphide** *Realgar*. As_2S_2 . A red *insoluble* poisonous powder, m.p. 307°C ., used in the manufacture of fireworks.
- arsenic trioxide** White arsenic, arsenious oxide, arsenious anhydride. As_2O_3 . A white *amorphous* powder used in the manufacture of *pigments* and as an *insecticide*.
- arsenic trisulphide** *Orpiment*. As_2S_3 . A yellow *soluble* solid, m.p. 300°C ., used as a *pigment*.
- arsenious acid** H_3AsO_3 . A solution of *arsenic trioxide* in water.
- arsenite** A *salt* of arsenious acid.
- arsine** Hydrogen arsenide. AsH_3 . An intensely poisonous colourless gas.
- artificial radioactivity** See *induced radioactivity*.
- aryl** An *organic univalent radical* derived from an *arene*; e.g. *phenyl*, C_6H_5 —, derived from *benzene*.
- asbestos** A variety of fibrous *silicate* minerals, mainly calcium magnesium silicate. Used as a heat-insulating material and for fire-proof fabrics.
- ascorbic acid** *Vitamin C*. $\text{C}_6\text{H}_8\text{O}_6$. A white crystalline *solid*, m.p. 192°C ., that occurs in fruits and vegetables. Deficiency causes scurvy.
- aseptic** Free from *bacteria*.
- ash** Incombustible residue left after the complete *combustion* of any substance. It consists of the non-volatile, *inorganic* constituents of the substance.
- asparagine** A white crystalline *soluble amino acid* obtained from some leguminous plants. See Appendix, Table 5.
- aspartic acid** Asparaginic acid, aminosuccinic acid. A white crystalline *amino acid* found in sugar beet. See Appendix, Table 5.
- asphalt** A black semi-solid sticky substance composed of *bitumen* with mineral matter. It consists mainly of complex *hydrocarbons*. Occurs naturally in asphalt lakes or in deposits mixed with *sandstone* and *limestone*; made artificially by adding mineral matter to bitumen. Used in road-making and building.
- aspirator** Apparatus for drawing a current of air or other gas through a *liquid*.
- aspirin** Acetylsalicylic acid. $\text{CH}_3\text{COOC}_6\text{H}_4\text{COOH}$. A white solid, m.p. 133°C ., used in medicine as an *antipyretic* and *analgesic*.
- assaying** Analysing for one constituent of a *mixture*, particularly the estimation of *metals* in *ores*.
- association** (chem.) Under certain conditions, e.g. in *solution*, the *molecules* of some substances associate into groups of several

ASTATIC COILS

molecules, thus causing the substance to have an abnormally high *molecular weight*. See *water*.

astatic coils An arrangement used in sensitive electrical instruments; the coils are arranged to give zero *resultant* external *magnetic field* when an *electric current* passes through them, and to have zero *electromotive force* induced in them by an external magnetic field.

astatic galvanometer A type of moving *magnet galvanometer*, in which two equal small magnets are arranged parallel but in opposition at the centres of two oppositely wound coils, the system being suspended by a fine torsion fibre. Since the resulting *magnetic moment* is zero, the Earth's *magnetic field* exerts no controlling *torque* on the moving system. Instead, the restoring torque is supplied by the suspending fibre and is made very small by using a fine *quartz fibre*; the sensitivity of the galvanometer is thus very large.

astatic pair of magnets. Arrangement of *magnets* used in *astatic galvanometers*.

astatine At. Element. At. No. 85. The last member of the *halogen* group and the only one without a stable *isotope*. The most stable isotope, $^{210}_{85}\text{At}$, has a *half-life* of only 8.3 hours.

asteroids Planetoids, minor *planets*. A belt of small bodies rotating round the *Sun* in orbits between those of *Mars* and *Jupiter*. The largest, *Ceres*, has a diameter of 685 km, but most are much smaller. It is thought that there are many thousands of these bodies.

astigmatism A defect of *lenses* (including the eye) caused by the curvature being different in two mutually perpendicular *planes*; thus *rays* in one plane may be in focus while those in the other are out of focus, producing distortion. Astigmatism of the eye is corrected by the use of cylindrical lenses.

astrigent A substance that by contracting body *tissues*, veins etc., reduces the discharge of mucus or *blood*.

astro-compass An instrument for determining direction relative to the *stars*. Unaffected by the errors to which *magnetic* or *gyro compasses* are subject, it is used to determine the errors of such instruments.

astrolabe An instrument used by early astronomers to measure the *altitude* of heavenly bodies. The simplest form consists of a graduated circular ring with a movable sighting arm. Now replaced by the *sextant*.

astrology The ancient art or pseudo-science of predicting the course of human destinies by indications derived from the positions and movements of the heavenly bodies.

astrometry The branch of *astronomy* concerned with measurements of the positions of celestial bodies on the *celestial sphere*.

astronautics The scientific study of travel outside the *Earth's atmosphere*.

astronomical unit The mean distance from the centre of the *Earth* to the centre of the *Sun*. 1.495×10^{11} metres, approximately 92.9×10^6 miles.

astronomy The scientific study of the heavenly bodies, their motions, relative positions, and nature. Its main branches are *astrometry*, *celestial mechanics*, and *astrophysics*. See also *radio astronomy* and *cosmology*.

astrophysics The branch of *astronomy* concerned with the physical properties of celestial bodies, and the interaction between *matter* and *energy* within them (and in the *space* between them).

asymmetric Not possessing *symmetry*.

asymmetric carbon atom A carbon *atom* in a *molecule* of an *organic compound* with four different atoms or groups attached to its four *valences*. Such a grouping permits of two different arrangements in *space*, leading to the existence of optical isomers. See *stereoisomerism*.

asymptote A line approaching a curve, but never reaching it within a finite distance.

atactic polymer A *polymer* in which the groups attached to the main chain are not arranged regularly. In isotactic polymers the same irregularity is repeated along the chain, whereas in syndiotactic polymers there are *asymmetric carbon atoms* in the chain and successive groups lie on alternate sides of the chain. Compare *tactic polymer*.

-ate Suffix used in the naming of chemical *compounds*; in the case of *salts*, denoting a salt of the corresponding *-ic acid*; e.g. *sulphate* from *sulphuric acid*.

athermancy The property of being opaque to *radiant heat*; i.e. of absorbing heat radiations.

atherodyde Athodyd. See *ram jet*.

atmolysis The separation of a *mixture* of *gases* through the walls of a porous vessel by taking advantage of the different rates of *diffusion* of the constituents.

atmometer Evaporometer. An instrument for measuring the rate of *evaporation* of *water*.

atmosphere The gaseous envelope surrounding the *Earth* (or other heavenly body). The composition of the *Earth's atmosphere* varies very slightly in different localities and according to altitude. Volume composition of dry air at sea-level (average values): nitrogen, 78.08%; oxygen, 20.95%; argon, 0.93%; *carbon dioxide*, 0.03%; neon, 0.0018%; helium, 0.0005%; krypton, 0.0001%; xenon, 0.00001%. Air generally contains, in addition to the above, *water vapour*, *hydrocarbons*, *hydrogen peroxide*, *sulphur compounds*, and dust particles in small and very variable amounts. See also *upper atmosphere*.

atmosphere A unit of *pressure*. The pressure that will support a column of mercury 760 mm high (29.92 inches) at 0°C., sea-level and

ATMOSPHERICS

latitude 45°. 1 normal atmosphere = 101 325 *newtons* per square metre = 14.72 lb/sq in (approx.). Atmospheric pressure fluctuates about this value from day to day.

atmospherics Electrical discharges that take place in the atmosphere, causing crackling sounds in *radio* receivers.

atom The smallest portion of an *element* that can take part in a *chemical reaction*. See *atom, structure of*; *atomic theory*.

atom, structure of The *atom* consists of a positively charged central core, the *nucleus*, surrounded by one or more negatively charged planetary *electrons*. The openness of atomic structure is indicated by the following approximate dimensions:

Effective radius of atom	10^{-10}m
Effective radius of nucleus	10^{-14}m
Effective radius of electron	10^{-15}m

Almost all the *mass* of the atom resides in the nucleus, which is composed of two different types of stable particle of almost equal mass, the *proton*, which is positively charged, and the *neutron*, which is electrically neutral. The mass of the electron is 1/1836th of that of the proton, and although its charge is opposite in sign, it is numerically equal to that of the proton. The number of planetary electrons in the electrically neutral atom is therefore equal to the number of protons in the nucleus. The chemical behaviour of an atom is determined by its number of planetary electrons (characterized by the *atomic number*), chemical combination between atoms taking place by the transfer or sharing of outer electrons between combining atoms. See *valence, electronic theory of*.

According to the *Bohr theory*, the planetary electrons of an atom were to be thought of as moving in well defined *orbits* about the nucleus, corresponding to specific *energy levels*—the emission or absorption of a *photon* of *electromagnetic radiation* occurring when an electron made a *quantum* jump from one permitted orbit, or energy level, to another (see *quantum numbers*). In the more modern wave *mechanics* the electrons are regarded as having a dual wave particle existence, which is expressed mathematically by a *wave function*. The precise position of the electron in the Bohr model of the atom is therefore replaced in the wave mechanical model by a *probability* that a particular planetary electron, visualized as a particle, may be found at a particular point in the path of a wave. Thus, in this model the atom is visualized as a central nucleus surrounded by a distribution of probabilities that individual electrons will exist at certain points at certain instants of time.

Atoms of an *element* that have the same number of protons, *p*, in their nuclei, but a different number of neutrons, *n*, are called *isotopes* of that element. When a particular isotope is being considered the following notation is used: to the chemical *symbol* of the element, the *mass number* (*n + p*) of the isotope is added as a

superscript. The atomic number of the element may also be added as a subscript; e.g. ${}^1_1\text{H}$, ${}^{12}_6\text{C}$, ${}^{197}_{79}\text{Au}$, are the most abundant isotopes of hydrogen, carbon, and gold.

atomic bomb See *nuclear weapons*.

atomic clock A very accurate form of clock in which the basis of the time scale is derived from the vibrations of *atoms* or *molecules*. See *ammonia clock*; *caesium clock*.

atomic constants See Appendix, Table 2.

atomic energy See *nuclear energy*.

atomic heat The numerical product of the *atomic weight* and the *specific heat capacity* of an *element*. *Dulong and Petit's law* states that the atomic heat of all *solid* elements is approx 25 joules per mole per degree. The law is obeyed by many elements at ordinary *temperatures*, but at lower temperatures the atomic heat of all elements falls below this value, tending to zero as *absolute zero* of temperature is approached.

atomic mass The *mass* of an *isotope* of an *element* measured in *atomic mass units*.

atomic mass unit Dalton. AMU. A unit used for expressing the masses of individual *isotopes* of *elements*: approximately equal to 1.66×10^{-27} kg. Formerly defined so that the most abundant isotope of oxygen, ${}^{16}_8\text{O}$, had a mass of 16 atomic mass units. In 1961 the 'unified atomic mass unit' was defined as 1/12 of the mass of an atom of ${}^{12}_6\text{C}$, and was adopted by the International Union of Pure and Applied Physics and the International Union of Pure and Applied Chemistry. *Atomic weights* given in this dictionary are based upon this scale. See Appendix, Table 3.

atomic nucleus See *nucleus, atomic*.

atomic number Proton number. *Z*. The number of *electrons* rotating round the *nucleus* of the neutral *atom* of an *element*, or the number of *protons* in the nucleus. (See *atom, structure of* and Appendix, Table 3.

atomic orbital See *orbital*.

atomic pile The original name for a *nuclear reactor*.

atomic theory Hypothesis as to the structure of *matter*, foreshadowed by Democritus, put forward as a formal explanation of chemical facts and laws by Dalton in the beginning of the nineteenth century. It assumes that matter is made up of small indivisible particles called *atoms*; the atoms of any one *element* are identical in all respects, but differ from those of other elements at least in *mass*. Chemical *compounds* are formed by the union of atoms of different elements in simple numerical proportions. Modern views on the structure of the atom (see *atom, structure of*) diverge considerably from Dalton's hypothesis, but it is still of value in affording a simple explanation of the laws of *chemical combination*.

ATOMIC VOLUME

atomic volume The *atomic weight* of an *element* divided by its *density*.

atomic weight Relative atomic mass. The ratio of the average mass per atom of a specified isotopic composition of an *element* to 1/12 of the mass of an atom of $^{12}_6\text{C}$. The natural isotopic composition is assumed unless otherwise stated. The atomic weights of the elements are given in the Appendix, Table 3.

atom smasher A popular name for an *accelerator*.

ATP See *adenosine triphosphate*.

atropine $\text{C}_{17}\text{H}_{23}\text{NO}_3$. A colourless crystalline *insoluble alkaloid*, m.p. 115°C .; extremely poisonous, has a powerful effect upon the nervous system, used in medicine to dilate the pupil of the eye. Occurs in the deadly nightshade and henbane.

attenuation (phys.) The loss of *power* suffered by *radiation* as it passes through *matter*.

atto- Prefix denoting one million million millionth; 10^{-18} . Symbol a, e.g. am = 10^{-18} metres.

aubepine See *anisaldehyde*.

audibility, limits of The limits of *frequency* of *sound* waves that are audible as sound to the human ear. The lowest is about 30 *hertz*, corresponding to a very deep vibrating rumble, and the highest in the region of 20 000 *hertz*, corresponding to a shrill hiss.

audio-frequency A *frequency* between 30 and about 20 000 *hertz*, which in the case of *sound* waves would be audible.

audiometer An instrument for measuring the level of human hearing.

Auer metal A *pyrophoric alloy* of 65% *misch metal* (a mixture of cerium and other metals) and 35% iron. Used as 'flint' in lighters.

Auger effect The emission of an *electron* by an *atom*, without the emission of X- or γ -*radiation*, as a result of a change from an excited state (see *excitation*) to a lower energy state. Named after Pierre Auger (born 1899).

Aureomycin* Chlortetracycline. $\text{C}_{22}\text{H}_{23}\text{N}_2\text{O}_8\text{Cl}$. A broad-spectrum *antibiotic* used against many *organisms* that are resistant to *penicillin*; also used to stimulate growth of animals.

auric Containing *trivalent* gold.

auric chloride Gold chloride. AuCl_3 . A red *soluble* crystalline solid, used in *photography* and in gilding glass.

auriferous Gold-bearing.

aurora borealis, Northern lights. A display of coloured light streamers and glows, mainly red and green, visible in the regions of the North and South Poles. Probably caused by streams of electrified particles from the *Sun*; most prominent when large *sunspots* are observed. In southern latitudes the effect is called the aurora Australis. See *solar wind*.

aurous Containing *univalent* gold.

austenite A *solid solution* of carbon or of iron carbide in the *gamma* form of iron; normally stable only at high *temperatures*, but may be

- preserved at normal temperatures by certain alloying *elements* or by rapid cooling.
- autocatalysis** *Catalysis* in which the catalyst is produced during the course of the *reaction* that is being catalysed.
- autoclave** a thick-walled vessel with a tightly fitting lid, in which substances may be heated under pressure to above their *boiling points*. Used in the manufacture of chemicals, for sterilizing medical instruments, etc., and in cooking.
- autolysis** The self-destruction of biological *cells* after death, as a result of the action of their own *enzymes*.
- automation** The application of mechanical, or more commonly *electronic* or computerized, techniques to minimize the use of manpower in any process.
- autoradiograph** An image obtained by placing a thin biological or other specimen, containing a *radioactive isotope*, in contact with a photographic plate, exposing for a suitable period and *developing*. The image shows the distribution of the radioactive *element* in the specimen.
- autosome** Any *chromosome* other than a sex chromosome.
- auxins** A type of *plant hormone* that promotes the elongation and growth of plant *cells* and stimulates rooting; e.g. *indole-3-acetic acid*.
- avalanche** (phys.) A *shower* of particles caused by the collision of a high energy particle (e.g. a *cosmic ray*) with any other form of *matter*.
- Avogadro constant** Avogadro's number. The number of atoms or molecules in a mole of a substance: $6.022\ 52 \times 10^{23}\ \text{mol}^{-1}$. Symbol L or N_A .
- Avogadro's Law** Avogadro's hypothesis. Equal *volumes* of all gases contain equal numbers of *molecules* under the same conditions of *temperature* and *pressure*. Named after Count Amadeo Avogadro (1776-1856).
- avoirdupois weights** System of *weights* used in the English-speaking countries. See *weight*, *British units of*.
- axis** An imaginary line about which a given body or system is considered to rotate.
- axis of mirror** See *mirrors*, *spherical*.
- axis of symmetry** A line about which a given figure is symmetrical; e.g. the diameter of a *circle*.
- axon** A long nerve fibre that carries impulses away from the body of a *neurone*.
- azeotrope** Constant-boiling mixture. A mixture of two or more liquids that distils at a certain constant *temperature* and has a constant composition at a given *pressure*. Its boiling point may be a maximum or a minimum relative to the original components.

AZIDE

azide A compound containing the univalent azido group, $-\text{N}_3$, e.g. sodium azide, NaN_3 . A derivative of hydrazoic acid.

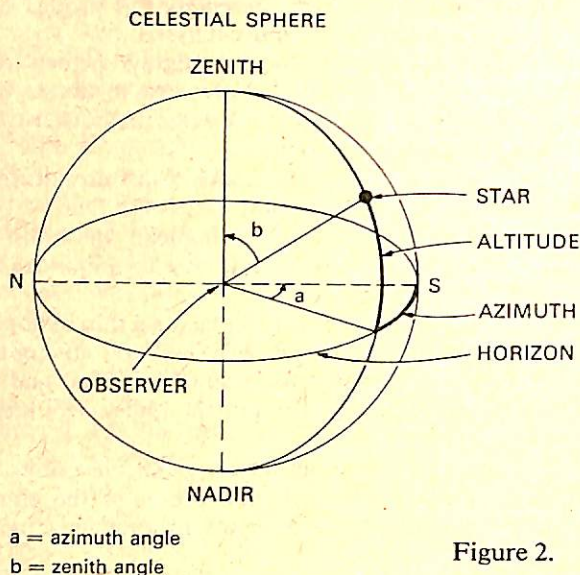


Figure 2.

azimuth (astr.) The *angular distance* from the north or south point of the horizon to the foot of the vertical circle through a heavenly body. The azimuth of a horizontal direction is its deviation from the north or south. See Fig. 2.

azimuthal quantum number See *quantum number*.

azines Organic derivatives of hydrazine, of the general formula $\text{RR}'\text{C} = \text{N}-\text{N} = \text{CRR}'$, where R and R' are univalent organic radicals. The suffix -azine is also used in systematic naming of six-membered unsaturated heterocyclic compounds containing nitrogen in the ring. Such compounds are sometimes described as azines.

azino The quadrivalent radical $= \text{N.N} =$

azo compound A compound containing an azo group attached to two carbon atoms ($-\text{CN}:\text{NC}-$). Aromatic azo compounds are usually prepared by azo coupling.

azo coupling The formation of an azo compound by the reaction of an aromatic diazo compound with a suitable nucleophilic reagent, such as an amine or a phenol.

azo dyes These azo compounds include dyes of many application classes (acid, direct, disperse, azoic, etc.).

azoic dyes Insoluble azo dyes that are formed within the fibre by the azo coupling of a diazo compound with a suitable azo-coupling component, often a naphthol derivative.

AZURITE

azote Former name for *nitrogen*.

azurite Natural basic copper carbonate, blue in colour.
 $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$.

B

Babbitt metal A class of *alloys* with a high proportion of tin, and small amounts of copper and antimony. Part of the tin may be replaced by lead. Used for bearings. Named after I. Babbitt (1799-1862).

Babo's law The addition of a non-volatile *solid* to a *liquid* in which it is *soluble* lowers the *vapour pressure* of the *solvent* in proportion to the amount of substance dissolved. Named after Clemens von Babo (1818-99).

bacillus In general, a rod-shaped *bacterium*. In particular, a genus of spore-producing bacteria.

back E.M.F. of cell When the poles of a *cell* become polarized (see *polarization*, *electrolytic*) a back *E.M.F.* is set up opposing the natural *E.M.F.* of the cell.

back E.M.F. of electric motor *E.M.F.* set up in the coil of an *electric motor*, opposing the current flowing through the coil, when the *armature* rotates.

background (phys.) The counting rate of a *counter tube* caused by sources other than the one being measured. Due primarily to natural *radioactivity* in the soil, and *cosmic rays*.

backing storage *Computer stores* with a capacity to store enormous quantities of information, but with an *access time* much greater than the main store. The commonest types are *magnetic tape* decks, fixed magnetic disc stores, and exchangeable magnetic disc stores.

bactericide A substance that kills *bacteria*.

bacteriology The study of *bacteria*.

bacteriophage Phage. A *virus* that requires a *bacterium* in which to replicate.

bacterium A cellular *microorganism* incapable of *photosynthesis*. Usually single celled and usually reproduced by *mitosis* although there are exceptions. Bacteria are the causes of many diseases, most of which can now be treated by the use of *antibiotics*. However, bacteria also perform an indispensable function in nature by bringing about the decay of plant and animal debris in the *soil*. Bacteria are broadly classified by their shape into three main groups: the spherical or *coccus* form, the spiral-shaped organism called a *spirillum*, and the rod-shaped or *bacillus* type.

Bakelite* Trade name for various synthetic *resins* of which *phenolformaldehyde resins* are amongst the most widely known. Named after Leo Hendrick Baekeland (1863-1944).

baking powder A *mixture* that produces *carbon dioxide* gas, CO_2 , on wetting or heating, thus causing the formation of bubbles in dough

and making it 'rise'. Usually contains *sodium hydrogen carbonate*, NaHCO_3 , and *tartaric acid* or *cream of tartar*.

baking soda *Sodium hydrogen carbonate*, NaHCO_3 .

balance An apparatus for weighing. In principle consists of a lever with two equal arms, with a pan suspended from the end of each arm. Masses placed in the pans are subject to pulls of *gravity*; when these forces are equal, as indicated by the beam being horizontal, the masses themselves must be equal. Sensitive balances have beam and pans poised on knife-edges of *agate* resting on agate surfaces. An accurate balance will weigh to the nearest 0.0001 g. More sensitive balances have been designed for special work, for example, *micro-balances* have been made which are capable of detecting differences in weight of only 0.25×10^{-6} milligram in a load of 250 milligrams.

balanced reaction See *chemical equilibrium*.

balata A natural *rubber*-like material very similar to *gutta-percha*.

ballistic galvanometer An instrument for measuring the total quantity of *electricity* passing through a circuit due to a momentary current. Any *galvanometer* may be used ballistically provided that its period of oscillation is long compared with the time during which the current flows.

ballistic missile A ground-to-ground missile with a parabolic flight path. A missile that is propelled and guided only during the initial phase of its flight.

ballistic pendulum A device for measuring the *velocity* of a *projectile*, such as a bullet. It consists of a large *mass* freely suspended from a horizontal beam and a means of measuring the displacement of the mass when it is struck by the projectile. The displacement of the mass is a function of the projectile's velocity.

ballistics The study of the flight path of *projectiles*.

Balmer series The visible *spectrum* of hydrogen. It consists of a series of sharp distinct lines, the *wavelengths*, λ , of which may be represented by the formula:

$$1/\lambda = R(1/2^2 - 1/n^2);$$

$n = 3, 4, 5$, etc., R is a constant known as *Rydberg's Constant*, which has the value $1.096\,77 \times 10^7 \text{ m}^{-1}$. Named after J. J. Balmer (1825-98).

band spectrum An *emission* or *absorption spectrum* consisting of a number of fluted bands each having one sharp edge. Each band is composed of a large number of closely spaced lines. Band spectra arise from *molecules*.

band theory See *energy bands*.

bandwidth The range of *frequencies* within which the performance of a *circuit*, *receiver*, or *amplifier* does not differ from its maximum value by a specified amount. The bandwidth of a *radio* emission is

BAR

- the width of the *frequency band* that carries a specified proportion (usually 99%) of the total power radiated.
- bar** Unit of pressure in the C.G.S. system; a pressure of 10^6 dynes per sq cm. Equivalent to a pressure of 0.986 923 atmosphere (approx. 75 cm of mercury). 1 bar = 10^5 newtons per sq metre.
- barbitone** Barbitol, 5,5-diethyl barbituric acid. $\text{CO}(\text{HNCO})_2(\text{C}_2\text{H}_5)_2$. A crystalline substance derived from *barbituric acid*, m.p. 191°C ., used in the form of its sodium salt as a *hypnotic*.
- barbiturates** Class of *organic compounds* derived from *barbituric acid*. Many of these compounds have a powerful soporific effect. They were formerly used extensively in sleeping tablets, but as an overdose could be fatal they have been largely replaced by safer substances.
- barbituric acid** Malonylurea. $\text{CO}(\text{NH.CO})_2\text{CH}_2$. A white crystalline powder, m.p. 248°C ., used in the synthesis of drugs and *plastics*.
- Barff process** Prevention of rusting of iron by the action of *steam* upon the surface of the red-hot metal, resulting in a surface coating of black oxide of iron, Fe_3O_4 .
- barium** Ba. Element. A.W. 137.34. At. No. 56. A silvery-white soft metal, which tarnishes readily in air. R.d. 3.5, m.p. 710°C . It occurs as *barytes*, BaSO_4 , and as *barium carbonate*, BaCO_3 . Compounds resemble those of calcium but are poisonous. Compounds are used in the manufacture of *paints*, *glass*, and fireworks.
- barium carbonate** BaCO_3 . A heavy white poisonous *insoluble* powder, used in rat poisons and various industries.
- barium hydroxide** Caustic baryta. $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$. A white poisonous crystalline solid, m.p. 78°C ., used for recovering sugar from waste molasses, for refining *vegetable oils*, and in *glass* manufacture.
- barium oxide** Baryta. BaO . A white crystalline powder, m.p. 1923°C ., used as a dehydrating agent and in the manufacture of *glass*.
- barium peroxide** BaO_2 . A white *insoluble* powder, m.p. 450°C ., used as a bleaching agent.
- barium sulphate** Blanc fixe. BaSO_4 . A white crystalline *insoluble* powder, m.p. 1580°C ., used as a *pigment* and, because it is *opaque* to X-rays, as the basis of 'barium meal' in X-ray diagnosis.
- barium titanate** BaTiO_3 . A crystalline substance with good *ferroelectric* and *piezoelectric* properties, used in *transducers*.
- Barkhausen effect** The effect observed when a *ferromagnetic substance* is magnetized by a slowly increasing *magnetic field*; the magnetization does not take place continuously, but in a series of small steps. The effect is due to orientation of *magnetic domains* present in the substance. Named after H. Barkhausen (1881-1956).
- barn** Unit of area for measuring the cross-section of *nuclei*. 1 barn equals 10^{-24} sq cm.
- barograph** An instrument used in *meteorology* for recording on paper the variations in atmospheric pressure over a period of time.

- barometer** An instrument for measuring atmospheric pressure. A mercury barometer consists of a long tube closed at the upper end filled with mercury and inverted in a vessel containing mercury; the vertical height of the mercury column that the atmospheric pressure is able at any time to support being taken as the atmospheric pressure at that time. See also *aneroid* barometer.
- barrier-layer rectifier** A *rectifier* that consists of a *semiconductor* between rectifying and non-rectifying metal *electrodes*.
- barycentre** *Centre of mass*: particularly the centre of mass of the *Earth/Moon* system.
- barye** Unit of pressure in the *c. g. s. system*, equal to one *dyne* per sq cm.
- baryon** A collective name for *nucleons* and *hyperons*. They are all *hadrons* and are believed to consist of three *quarks* bound together. The number of baryons minus the number of corresponding anti-baryons taking part in a process is called the baryon number—a quantity that appears to be conserved in all processes. All baryons have *spin* $\frac{1}{2}$. See Appendix, Table 6.
- baryta** See *barium oxide*.
- barytes** Heavy spar. Natural *barium sulphate*, BaSO_4 .
- basalt** A rock of volcanic origin, chemically resembling *feldspar*.
- base** (chem.) A substance that liberates *hydroxyl ions* in solution, reacts with an *acid* to form a *salt* and water only, has a tendency to accept *protons*, and turns *litmus* blue. Bases include *oxides* and *hydroxides* of metals and *ammonia*. See also *organic base*; *Lewis acids and bases*.
- base** (math.) 1. The horizontal line upon which a geometric figure stands. 2. The number that is a starting point for a numerical or logarithmic system. E.g. the *binary notation* is a numerical system to the base 2; common *logarithms* are to the base 10.
- base** (phys.) The part of a *transistor* that separates the *emitter* from the *collector*.
- base exchange** Cation exchange. See *ion exchange*.
- base metals** In contradistinction to the *noble metals*, metals that corrode, tarnish, or oxidize on exposure to air, moisture, or heat.
- base unit** A unit that is defined in terms of a primary standard, e.g. the unit of mass (*kilogram*) in *SI units*. A derived unit is defined in terms of these base units, e.g. the unit of force (*newton*) in *SI units*.
- basic** (chem.) Having the properties of a *base*; opposite to *acidic*; reacting chemically with *acids* to form *salts*.
- basic dyes** Cationic dyes. A group of *dyes* that are *organic bases*, the *cations* of which are the colouring agents.
- basic salt** A *salt* formed by the partial neutralization of a *base*; it consists of the normal salt combined with a definite molecular proportion of the base. E.g. *white lead*, *basic lead carbonate*, $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.

BASIC SLAG

basic slag An impure *mixture* of tetracalcium phosphate, $\text{Ca}_4\text{P}_2\text{O}_9$, *calcium silicate*, CaSiO_3 , *lime*, CaO , and *ferric oxide*, Fe_2O_3 . A by-product of *steel* manufacture, its high phosphorus content makes it a valuable *fertilizer*.

bath salts The main constituent is generally sodium sesquicarbonate, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$, or some other *soluble* sodium salt to soften the water. See *hard water*.

bathymetry Measurement of depth, especially of the sea.

battery A number of *primary* or *secondary cells* arranged in series or parallel. In series, they give a multiple of the *E.M.F.* of the cell; in parallel, they give the same *E.M.F.* as the cell, but have a greater capacity, i.e. a given current can be supplied for a longer period. The common 'dry batteries' usually consist of *Leclanché cells*.

Baumé scale A scale of *relative density* (specific gravity) of *liquids*. named after A. Baumé (1728-1804).

$$\text{Degrees Baumé} = 144.3 (\text{r.d.} - 1) / \text{r.d.}$$

bauxite Natural *hydrated aluminium oxide*, $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$. The most important ore of aluminium.

bauxite cement Ciment fondu. A rapid-hardening *cement* consisting mainly of calcium aluminate; made from *bauxite* and *lime* in an electric furnace.

beam (phys.) *Radiation* travelling in a particular direction.

beam hole A hole made in the shield, and usually through the *reflector*, of a *nuclear reactor* to permit the escape of a beam of radiation, particularly *neutrons*, for experimental purposes.

beam riding A method of *rocket* guidance in which the missile steers itself along the axis of a *beam of radiation*, usually a conically scanned *radar* beam.

beam transmission *Radio* transmission in which the *electromagnetic* waves are sent in a particular direction in a *beam* instead of being radiated in all directions.

bearing (math.) The direction of a point *B* from a fixed point *A*; stated either in terms of the angle the line *AB* makes with the line running due North and South through *A* (e.g. 20° East of North), or in terms of the angle the line *AB* makes with the line running due North through *A*, considered in a clockwise direction.

beat frequency The difference *frequency* resulting from the interaction between *radio frequency* signals of different *wavelengths*.

beats (phys.) A periodic increase and decrease in loudness heard when two notes of nearly the same *frequency* are sounded simultaneously. Caused by *interference* of *sound* waves, the number of beats produced per second is equal to the difference in frequencies of the two notes.

Beaufort scale A numerical scale for the estimation of wind force, based on its effect on common objects. Named after Admiral Sir

BENDING MOMENT

Beaufort number	Description of wind	Wind speed metres per sec.
0	Calm	< 0.3
1	Light air	0.3-1.5
2	Light breeze	1.6-3.3
3	Gentle breeze	3.4-5.4
4	Moderate breeze	5.5-7.9
5	Fresh breeze	8.0-10.7
6	Strong breeze	10.8-13.8
7	Near gale	13.9-17.1
8	Gale	17.2-20.7
9	Strong gale	20.8-24.4
10	Storm	24.5-28.4
11	Violent storm	28.5-32.6
12	Hurricane	> 32.7

F. Beaufort (1774-1857). The scale for various wind forces is given in the table.

Beckmann thermometer A sensitive *thermometer* for measuring small differences or changes in *temperature*. The quantity of mercury in the bulb can be varied by causing it to overflow into a reservoir at the top, thus enabling the thermometer to be used over various ranges of temperature. The scale covers 6-7 degrees and is graduated to 0.01 degree.

becquerel The derived *SI unit* of *activity* (radioactive). The number of atoms of a radioactive substance that disintegrate in one second. Symbol Bq. Named after Antoine Henri Becquerel (1852-1908).

beeswax A whitish *wax* consisting of a *mixture* of *compounds*, secreted by bees for the purpose of building their honeycombs. Used in polishes and cosmetics.

beet sugar Sucrose. $C_{12}H_{22}O_{11}$. Obtained from the sugar beet; chemically identical with *cane sugar*.

behenic acid See *docosanoic acid*.

bel Ten *decibels*.

bell, electric A simple device making use of the magnetic effect of an *electric current*. Closing the switch (see Fig. 3 overleaf) causes a current, provided by a *cell*, to flow through a small *electromagnet*. This then attracts a piece of soft iron attached to a hammer, causing the latter to strike the gong of the bell. The movement of the iron breaks the circuit; the current ceases to flow through the electromagnet, and the iron and attached hammer spring back into their original position, thus closing the circuit again; this process continues as long as the switch is closed.

bell metal An *alloy* of copper (60%-85%) and tin.

bending moment The bending moment about any point in a loaded beam is the *algebraic sum* of the *moments* of all the vertical forces to one side of that point.

BENEFICIATION

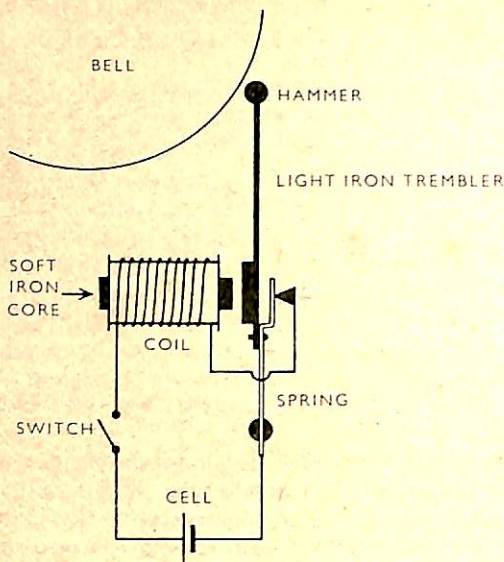


Figure 3.

beneficiation The separation of *ores* into valuable components (concentrates) and wastes (gangue). It can be achieved in various ways; e.g. by *flotation*.

bentonite A clay-like material similar to *fuller's earth*.

benzaldehyde C_6H_5CHO . A colourless oily *liquid*, b.p. $178.1^\circ C$., with a smell of almonds. Used as a *solvent*, in the manufacture of *dyes*, and in perfumes.

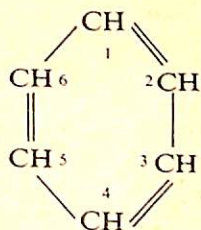
benzal group See *benzylidene*.

Benzedrine* See *amphetamine*.

benzene Benzol. C_6H_6 . A colourless *liquid aromatic hydrocarbon* found in *coal-tar*, b.p. $80.1^\circ C$. Used as a *solvent*, in motor fuel, and in the manufacture of numerous *organic compounds*.

benzene ring In the *benzene* molecule the six carbon atoms are joined in a hexagon known as the benzene ring, generally represented by the Kekulé formula in which hydrogen and carbon have their usual *valences* of one and four respectively, and the carbon atoms are linked by alternating single and double *valence bonds*. Derivatives are formed by substitution of the hydrogen atoms, positions being indicated by numbering the ring as shown.

Although this has been shown to be incorrect as a representation of the actual state of a benzene molecule, this 'classical' formula with alternating double bonds but with a geometrically correct



usually abbreviated to:



arrangement of atoms can be used as one of a number of reference formulae with different classical bond arrangements, the most important of which is also a Kekulé formula with the double bonds in the other three alternate positions. These reference formulae of nonexistent forms of benzene, known as *resonance* (mesomeric) structures, can be used in the description of the actual, highly stable, state of the benzene molecule, treated as a resonance hybrid of all the contributing structures. This quantum-mechanical resonance is general for all molecules; thus, $\text{H}-\text{Cl}$ and H^+Cl^- are resonance forms of the hydrogen chloride molecule. It is distinct from an equilibrium between actually existing interconvertible forms, as in the case of *tautomerism*.

In *structural formulae* the benzene molecule is usually represented either as shown above, or by a simple hexagon without showing the double bonds.

benzenesulphonic acid $\text{C}_6\text{H}_5\text{SO}_3\text{H}$. A crystalline *soluble* solid, m.p. 52.5°C ., used in organic synthesis and as a *catalyst*.

benzidine $\text{NH}_2\text{C}_6\text{H}_4\text{C}_6\text{H}_4\text{NH}_2$. An *aromatic* base, m.p. 128°C ., of importance in the dyestuff industry.

benzine Petroleum benzin, petroleum ether, solvent naphtha. A mixture of *hydrocarbons* (mainly *alkanes*) obtained from petroleum; it boils between 35 and 80°C . and is used as a solvent. Because of possible confusion with *benzene*, the word 'benzine' should be avoided in scientific writing.

benzoate A *salt* or *ester* of *benzoic acid*.

benzoic acid $\text{C}_6\text{H}_5\text{COOH}$. A white crystalline powder, the simplest of the *carboxylic acids* of the *aromatic* series, m.p. 122°C . Used as a food preservative, because it inhibits the growth of *yeasts* and *moulds*. Also used for this purpose in the form of its sodium *salt*, which is highly water *soluble*.

benzoin 1. $\text{C}_6\text{H}_5\text{CHOH.CO.C}_6\text{H}_5$. An *optically active* crystalline substance, m.p. $133-7^\circ\text{C}$., used in organic synthesis. 2. Gum Benjamin. A natural brown *aromatic resin* obtained from certain trees (*Styrax benzoin*), used in incense and in the manufacture of cosmetics and perfumes.

BENZOL

benzol Benzole. See *benzene*.

benzonitrile Phenyl cyanide. C_6H_5CN . A colourless poisonous *liquid*, b.p. $190.7^\circ C.$, used in organic synthesis.

benzophenone Diphenyl ketone. $C_6H_5COC_6H_5$. A crystalline *insoluble* solid, m.p. $48.1^\circ C.$, used in organic synthesis.

benzopyrene $C_{20}H_{12}$. A yellow crystalline *polycyclic hydrocarbon*, m.p. $179^\circ C.$, found in small quantities in *coal-tar*. It is a *carcinogen* and is one of the most harmful constituents of tobacco smoke.

benzoyl The *univalent radical* C_6H_5CO- .

benzoyl peroxide $(C_6H_5CO)_2O_2$. An *insoluble* crystalline explosive solid, m.p. $106-8^\circ C.$, used in bleaching flour, fats, oils, etc., and as a *catalyst*.

benzyl The *univalent radical* $C_6H_5CH_2-$.

benzyl alcohol $C_6H_5CH_2OH$. A colourless *aromatic liquid*, b.p. $205.3^\circ C.$, used as a *solvent* and in the manufacture of perfumes and flavours.

benzyl cellulose A *benzyl ether of cellulose*, possessing good electrical insulating properties and forming the basis of a *plastic material*.

benzylidene The *bivalent radical* $C_6H_5CH=$.

benzylidene chloride Benzal chloride. $C_6H_5CHCl_2$. A colourless oily *liquid*, b.p. $205.2^\circ C.$, used in the manufacture of *dyes*.

benzylidyne The *trivalent radical* $C_6H_5C=$.

berberine $C_{20}H_{19}NO_5$. A *soluble* crystalline *alkaloid*, m.p. $145^\circ C.$, used in the form of its *sulphate* or *hydrochloride* in medicine.

Bergius process A process for the manufacture of oil from *coal*. Coal, made into a paste with heavy oil, is heated with hydrogen under a pressure of 250 atmospheres to a *temperature* of $450^\circ-470^\circ C.$, in the presence of a *catalyst*. The carbon of the coal reacts with the hydrogen to give a mixture of various *hydrocarbons*. Named after F. Bergius (1884-1949).

berkelium Bk. *Transuranic element*. At. No. 97. A member of the *actinide series*. Most stable *isotope*, $^{247}_{97}Bk$, has a *half-life* of about 1400 years.

Bernoulli's theorem At any point in a tube through which a *liquid* is flowing, the sum of pressure energy, *potential energy*, and *kinetic energy* is constant. Named after Daniel Bernoulli (1700-1782).

Berthollide compounds Chemical *compounds* the composition of which does not conform to a simple ratio of *atoms* in the *molecule*.

beryl Natural beryllium silicate, $3BeO \cdot Al_2O_3 \cdot 6SiO_2$.

beryllium Glucinum. Be. Element. A.W. 9.0122, At. No. 4. A hard white *metal*, r.d. 1.85, m.p. $1280^\circ C$. It occurs as *beryl*, from which it is obtained by *electrolysis*. Used for light, corrosion-resisting *alloys*.

Bessemer process A process for making *steel* from *cast iron*. Molten iron from the *blast furnace* is run into the Bessemer converter, a large egg-shaped vessel with holes below. Through these, air is blown into the molten metal, and the carbon is oxidized. The

requisite amount of *spiegel* is then added to introduce the correct amount of carbon for the type of steel required. In some modern converters, instead of air a mixture of oxygen and steam is blown into the molten metal to avoid the absorption of nitrogen by the steel. This is known as the VLN (very low nitrogen) process. Named after H. Bessemer (1813-98).

beta decay A *radioactive* disintegration of an unstable *nucleus* in which a *neutron* changes to a *proton* with the emission of an *electron* and an antineutrino or in which a *proton* changes to a *neutron* with the emission of a *positron* and a *neutrino*. Thus a beta decay involves unit change of *atomic number* but no change of mass number. It is a form of *weak interaction*.

beta-iron An allotropic (see *allotropy*) form of pure iron, stable between 768°C. and 910°C., similar to *alpha-iron* except that it is non-magnetic.

beta particle An *electron* or *positron* emitted by a *radioactive nucleus*. See *beta decay*.

beta rays A stream of *beta particles*; they possess greater penetrating power than *alpha rays* and are emitted with velocities in some cases exceeding 98% of the *velocity* of light.

betatron A cyclic *accelerator* for accelerating a continuous beam of *electrons* to high speeds by means of the *electric field* produced by a changing magnetic flux. The electrons move in stable circular orbits in an evacuated *torus-shaped* chamber. By allowing the fast electrons to strike a metal target a continuous source of *gamma rays* with energies up to 300 MeV can be produced.

BeV See *GeV*.

bevatron A cyclic *accelerator* for accelerating *protons* and other particles to very high *energies* (up to 6 *gigaelectron volts*).

BHT See *Ionol*.

bi- Prefix denoting two; formerly used in chemical nomenclature to indicate an *acid salt* of a *dibasic acid*. See *bicarbonate*.

bicarbonate *Acid salt* of *carbonic acid*, H_2CO_3 ; carbonic acid in which half the *acidic hydrogen* has been replaced by a *metal*. E.g. sodium bicarbonate, NaHCO_3 . However the use of 'bi-' as a prefix in such compounds has now been abandoned and the correct name for this substance is *sodium hydrogen carbonate*.

bi-concave A term used to describe a *lens* that is *concave* on both sides. See Fig. 24 under *lens*.

bi-convex A term used to describe a *lens* that is *convex* on both sides. See Fig. 24 under *lens*.

big-bang theory See *superdense theory*.

bile An alkaline secretion of the liver of vertebrates important in the digestion of *fats*. It consists of *cholesterol*, bile salts (salts of *cholic acid*), and bile pigment (degradation products of *haemoglobin*).

BILLION

billion Million million, 10^{12} (British); thousand million, 10^9 (American).

bimetallic strip A strip composed of two different *metals* welded together in such a way that a rise of *temperature* will cause it to buckle as a result of unequal expansion. Used in *thermostats*.

bimorph cell Two plates of *piezoelectric* material joined together so that they bend in proportion to an applied *voltage*.

binary cell An element in a *computer* that can store information by virtue of its ability to remain stable in one of two possible states.

binary compound A chemical *compound* of two *elements* only. Denoted by the suffix -ide; e.g. *calcium carbide*, CaC_2 .

binary notation Binary number system. A system of numbers that has only two different *digits*, usually 0 and 1. There are several ways of representing numbers in the binary notation; one common method is given below. Because it has only two digits, which can be represented by an electric current switched on or switched off, this notation is used in *computers*.

<i>Decimal system</i>	<i>Binary system</i>
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010

binary stars Two *stars* gravitationally attracted to each other, so that they revolve around their common *centre of gravity*, thus forming a *double star*.

binding energy (phys.) The *energy* that must be supplied to a *nucleus* in order to cause it to decompose into its constituent *neutrons* and *protons*. The binding energy of a neutron or a proton is the energy required to remove a neutron or a proton from a nucleus.

binocular Any optical instrument designed for the simultaneous use of both eyes; e.g. binocular field-glasses.

binomial A mathematical expression consisting of the sum or difference of two terms; e.g. $a^2 - 3b$.

binomial nomenclature (bio.) The method of naming plants and animals introduced by Linnaeus in the mid-eighteenth century. Every plant or animal has two Latin names: a generic name designating its genus, and a specific name indicating the species; e.g. *Felis tigris*, the tiger.

binomial theorem The expansion of

$$(x + y)^n = x^n + nx^{n-1}y + n(n-1)x^{n-2}y^2/2! + \dots + y^n,$$

n being a positive *integer*. In general, for n not a positive integer, the following expression is valid if the numerical value of x is less than unity:

$$(1 + x)^n = 1 + nx + n(n-1)x^2/2! + \dots \text{to } \infty.$$

biochemical oxygen demand See *BOD*.

biochemistry The *chemistry* of living matter.

biodegradation Chemical *degradation* by biological influences; especially the breakdown of substances potentially detrimental to the environment in waste products, e.g. *detergents* in waste water.

biogenesis The biological doctrine that only life begets life, as opposed to the unsubstantiated theory that animate matter may still be spontaneously generated from inanimate matter. See *abiogenesis*.

biology The science of life, the main branches of which are *botany* and *zoology*. Other branches include *cytology*, *histology*, *morphology*, *physiology*, *embryology*, *ecology*, *genetics*, and *microbiology*. Related subjects are *biochemistry*, *biophysics*, and *biometry*.

bioluminescence A form of *luminescence* occurring in living creatures, such as fire flies, glow worms, etc. The light is emitted when the substance luciferin is oxidized in the presence of the enzyme luciferase.

biomass The mass of living matter in a population of particular organisms in a particular area.

biometry The application of mathematical and statistical methods to the study of *biology*.

biophysics The application of *physics* to the study of *biology*.

biosphere See *ecosphere*.

biosynthesis *Synthesis* of chemical compounds by living organisms.

biotin $C_{10}H_{16}O_3N_2S$. A crystalline substance, m.p. $230^\circ C$.; a *vitamin* of the B complex, also known as vitamin H, widely distributed in nearly all living *cells* in very small quantities. Appears to be of importance in the *metabolism* of *carbohydrates*, *fats*, and *proteins*.

biotype A group of individual *organisms* having the same genetic characteristics.

biphenyl Diphenyl. $C_6H_5C_6H_5$. An *insoluble* colourless powder, m.p. $70^\circ C$., used in organic synthesis and in the manufacture of *dyes*.

bi-prism An optical device for obtaining *interference* fringes; consists of two acute-angled *prisms* placed base to base.

Birkeland and Eyde process A process for the fixation of atmospheric nitrogen (see *fixation of nitrogen*), becoming obsolete. Nitrogen and oxygen from the atmosphere are made to combine to form *nitric oxide*, NO, by the action of an electric arc. Named after Kristian Birkeland (1867-1917) and Samuel Eyde (1866-1940).

BISECTION

bisection Division into two equal parts.

bisector A straight line that divides another line or angle into two equal parts.

bismuth Bi. Element. A.W. 208.98. At. No. 83. A white crystalline metal with a reddish tinge, r.d. 9.7, m.p. 271°C. It is a brittle, rather poor conductor of heat and electricity, that expands on solidifying. It occurs as the metal, or as the oxide, Bi_2O_3 , and is extracted by roasting the ore and heating with coal. Used in alloys of low melting point (see *Rose's metal*; *Wood's metal*); compounds are used in medicine.

bismuth nitrate $\text{Bi}(\text{NO}_3)_3 \cdot 5\text{H}_2\text{O}$. A colourless deliquescent crystalline substance that, with a large excess of water, forms basic bismuth nitrate (bismuth sub-nitrate), $\text{BiONO}_3 \cdot \text{H}_2\text{O}$, a crystalline substance, m.p. 105°C., used in medicine.

bismuth oxide chloride Bismuth oxychloride. BiOCl . A white crystalline insoluble powder, used in the manufacture of pigments and artificial pearls.

bit A unit of information in *information theory*. The amount of information required to specify one of two alternatives, e.g. to distinguish between 1 and 0 in the *binary notation* as used in computers. Also used as a unit of capacity in a store. See also *byte*; *character*; *word*.

bittern (chem.) The mother-liquor remaining after the crystallization of common salt, NaCl , from sea-water. Source of compounds of magnesium, bromine, and iodine.

bitumen A term covering numerous mixtures of hydrocarbons, more particularly solid or tarry mixtures, soluble in carbon disulphide.

bituminous Containing, or yielding upon distillation, bitumen or tar.

biuret Carbamoylurea. $\text{NH}_2\text{CONH} \cdot \text{CONH}_2 \cdot \text{H}_2\text{O}$. An insoluble crystalline substance formed from urea. See *biuret reaction*.

biuret reaction A chemical reaction in which an alkaline solution of biuret gives a purple colour on the addition of cupric sulphate. Used as a biochemical test for protein and urea.

bivalent Divalent. Having a valence of two.

black ash Impure sodium carbonate obtained in the *Leblanc process*.

black body radiation Full or complete radiation; radiation of all frequencies, such as would be emitted by an ideal 'black body', which absorbs all radiations falling upon it. As the absorptance of a black body is one, the radiation that it emits is a function of temperature only. See *Stefan's Law*.

blackdamp Carbon dioxide (in coal mines).

black hole A hypothetical region of space possessing a gravitational field so intense that no matter or radiation can escape from it. Such regions are believed to form when a star collapses, having used up all its nuclear fuel. Smaller stars create supernova explosions when

they die, leaving *neutron stars*: it is the more massive stars that are believed to create black holes.

The boundary of the black hole is thought to be a sphere (called the event horizon) with a radius (called the Schwartzchild radius) $2GM/c^2$, where M is the mass of the region, G is the *gravitational constant*, and c is the velocity of light.

The problem of detecting black holes is that, being unable to emit or reflect radiation, they are invisible. However, it is thought that some *X-ray binary stars* exist in which one member of the pair is a black hole.

blacklead Plumbago, graphite. Natural crystalline form of carbon. A soft grey-black *solid*; used for making vessels to resist high temperatures, in pencils, and as a lubricant.

blanc fixe Artificial *barium sulphate*, BaSO_2 . Used as an extender in the paint industry.

blanket (phys.) A layer of *fertile* material surrounding the core of a nuclear reactor to act as a reflector, or for the purpose of breeding new fuel. See *breeder reactor*.

blast furnace A furnace for the smelting of iron from iron oxide ores. It is constructed of *refractory* bricks covered with *steel* plates and charged from above with a mixture of the ore, *limestone* (CaCO_3), and *coke*. The coke is ignited at the bottom of the furnace by a blast of hot air; the *carbon monoxide* so produced reduces the iron oxide to iron, while the heat of the action decomposes the limestone into *carbon dioxide* and *lime*, CaO . The lime combines with the sand and other impurities in the ore to form a molten *slag*. The molten iron and the slag are tapped off at the bottom of the furnace. The resulting *pig-iron* or *cast iron* contains up to 4.5% carbon.

blasting gelatin Jelly-like mixture of *gun-cotton* with *nitroglycerin*. A very powerful *explosive*.

blastula A hollow ball of *cells* that forms in the very early embryonic development of animals.

bleaching Removing the colour from coloured materials by chemically changing the dyestuffs into colourless substances. *Bleaching powder* and other *oxidizing agents*, or *sulphur dioxide* and other *reducing agents* are often used.

bleaching powder Chloride of lime. A whitish powder, consisting mainly of calcium oxychloride, CaOCl_2 , with water; prepared by the action of chlorine on *calcium hydroxide*, Ca(OH)_2 . The action of *dilute acids* liberates chlorine, which acts as an *oxidizing agent* and so bleaches the material.

blende Natural *zinc sulphide*, ZnS .

blink microscope Blink comparator. An instrument for examining photographs of the sky taken in rapid succession to each other. Minor *planets* and *stars* with large *proper motions*, or rapid changes of *luminosity*, are thereby made conspicuous.

BLOOD

blood A *liquid* that circulates throughout the body of the higher animals, transporting oxygen and *cell* foods to all the component cells of the body, and removing their excretions. Blood consists of a liquid, *blood plasma*, in which *blood cells* are suspended. The average human male has about 11 pints (6.2 litres) of blood in his body.

blood cells Blood corpuscles, haemocytes. There are three types of blood cell: red corpuscles (*erythrocytes*), white corpuscles (*leucocytes*), and *blood platelets* (thrombocytes). The function of the red corpuscles is to transport oxygen throughout the body, by way of the *haemoglobin* that they contain. The function of the white cells is to combat infection.

blood plasma Blood from which all *blood cells* have been removed. Plasma is 90% water, in which the principal *solutes* are *proteins*, *salts*, *sugar*, and *urea*. -

blood platelets Thrombocytes. Small membrane-bounded coin-shaped particles that circulate in the *blood*. If a blood vessel should break, the platelets clump together to form a plug to stop the bleeding. Platelets contain substantial quantities of ATP, and it is the diphosphate that causes the agglutination. Human blood contains about 250 000 platelets per cubic millimetre.

blown oil A thickened *oil* made by blowing air through a natural vegetable or animal oil.

blowpipe A device for producing a jet of *flame* by forcing an inflammable gas mixed with air or oxygen through a nozzle at high pressure.

bluestone See *blue vitriol*.

blue vitriol Bluestone. Crystalline *cupric sulphate*, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. Used for copper plating and in *solution* for spraying plants.

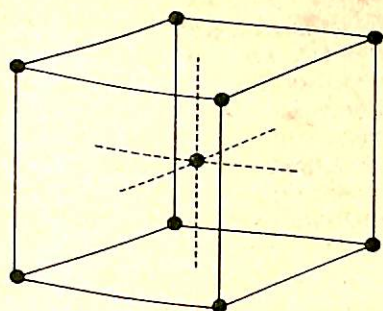
board of trade unit B.O.T. unit. A British unit of *electrical energy*, the *kilowatt-hour*. The energy obtained when a power of 1 *kilowatt* is maintained for 1 hour.

boart See *bort*.

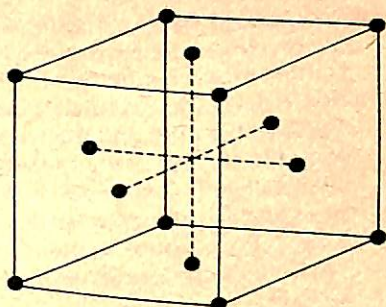
BOD Biochemical (or biological) oxygen demand. A measure of the content of organic matter in water and wastes. It is the amount of oxygen (mg of O_2 per cubic decimetre of water) when a sample containing a known mass of oxygen in solution is kept at 20°C . for five days. The oxygen is consumed by microorganisms that feed on the organic matter in the sample.

body-centred A *crystal* is said to be body-centred when there is a *lattice* point at the centre of the body of the crystal as well as at the corners. It is said to be 'face-centred' when there is a lattice point at the centre of each face. See Fig. 4.

bog iron ore Impure form of *hydrated ferric oxide*, $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, found in bogs and marshes.



BODY-CENTRED
CUBIC CRYSTAL



FACE-CENTRED
CUBIC CRYSTAL

Figure 4.

Bohr theory of hydrogen atom spectrum. Theory of the atom put forward by Niels Bohr (1885-1962) to explain the *line spectrum* observed for hydrogen (see *Balmer series*). Based on three postulates: 1. The *electrons* rotate in certain *orbits* round the *nucleus* of the atom without radiation energy in the form of *electromagnetic waves*. 2. These orbits are such that the *angular momentum* of the electron about the nucleus is an *integral* multiple of $h/2\pi$, where h = *Planck's constant*. 3. Emission or absorption of radiation occurs when an electron jumps from one of these so-called *stationary states* of energy E_1 to another of energy E_2 , the frequency, ν , of the emitted (or absorbed) *light* being given by $E_1 - E_2 = h\nu$. If E_1 is greater than E_2 , light is emitted; conversely, light is absorbed. See *quantum mechanics*. This theory has now been superseded by the application of *wave mechanics*, which has shown that for the hydrogen atom spectrum, Bohr's theory is a very good approximation. Wave mechanics has the advantage of requiring no *ad hoc* assumptions and can deal more effectively with the problem of atoms with two or more electrons. (See also *atom, structure of.*)

boiled oil *Linseed oil* boiled with, or containing, a drying agent such as *lead monoxide*, PbO . Used in *paints*.

boiling Ebullition. The state of a *liquid* at its *boiling point* when the maximum *vapour pressure* of the liquid is equal to the external pressure to which the liquid is subject, and the liquid is freely converted into *vapour*.

boiling point B.p. The *temperature* at which the maximum *vapour pressure* of a *liquid* is equal to the external pressure; the temperature at which the liquid boils freely under that pressure. Boiling points

BOILING WATER REACTOR

are normally quoted for standard atmospheric pressure, i.e. 760 mm of mercury.

boiling water reactor BWR. A *nuclear reactor* in which *water* is used as *coolant* and *moderator*. *Steam* is thus produced in the reactor under pressure, and can be used to drive a *turbine*.

bolide A large bright *meteor*; some of these objects explode on entering the *Earth's atmosphere*.

bolometer An extremely sensitive instrument for measuring *heat radiations*. Consists essentially of two very thin, blackened platinum gratings, forming two arms of a *Wheatstone bridge circuit*. Radiant heat falling upon one of the gratings raises its electrical *resistance*, thus causing a deflection of the needle of a *galvanometer* in the circuit.

Boltzmann's constant $k = R/L = 1.380\,622 \times 10^{-23}$ joule per kelvin, where R = the *gas constant* and L = *Avogadro constant*. Named after L. Boltzmann (1844-1906).

bomb calorimeter A strong metal vessel used for measuring *heats of reaction*, especially *heats of combustion*; e.g. for determining the *calorific value* of a *fuel*. To do this, a known *weight* of the substance under test is burnt in the vessel, and by measuring the quantity of heat produced, the calorific value is calculated.

bond Valence bond, linkage. A representation of a *valence* link by which one *atom* is attached to another in a chemical *compound*.

bond energy The *energy* characterizing a chemical *bond* between two *atoms*. Measured by the energy required to separate the two atoms.

bond length The distance between the *nuclei* of two *atoms* joined by a chemical *bond*.

bone ash Ash obtained by heating bones in air. Consists mainly of *calcium phosphate*, $\text{Ca}_3(\text{PO}_4)_2$.

bone black See *animal charcoal*.

bone char See *animal charcoal*.

bone oil Dippel's oil. Product obtained by the *destructive distillation* of bones. Dark oily evil-smelling liquid used as a source of *pyridine*.

Boolean algebra A branch of symbolic logic used in *computers*. Logical operations are performed by operators such as 'and', 'or', 'not-and' in a way analogous to mathematical signs. Named after George Boole (1815-64).

booster See *rocket*.

boracic acid See *boric acid*.

boranes *Hydrides* of boron, having the general formula B_nH_{n+2} ; the boron analogues of *alkanes*.

borate A salt or ester of *boric acid*.

borax See *sodium tetraborate*.

borax bead test A chemical test for the presence of certain *metals*. A bead of *borax* fused in a wire loop will react chemically with the *salts* of a number of metals, often producing colours which help to

identify the metal; e.g. manganese compounds give a violetbead, cobalt a deep blue.

Bordeaux mixture A mixture of cupric sulphate, CuSO_4 , calcium oxide, CaO , and water. Used for spraying plants as a fungicide for plant diseases.

boric acid Orthoboric acid, boracic acid. H_3BO_3 . A white crystalline soluble solid. Occurs naturally in volcanic regions; also manufactured from borax. Used as a mild antiseptic and in various industries.

boric oxide Boric anhydride. B_2O_3 . An oxide that exists either as a transparent crystalline substance, m.p. 460°C ., or a transparent amorphous glass. Used in the manufacture of special glasses.

boride A binary compound with boron.

borneol Bornyl alcohol. $\text{C}_{10}\text{H}_{17}\text{OH}$. A white optically active translucent solid, m.p. 210.5°C ., used in the manufacture of synthetic camphor and in perfumes.

bornyl acetate $\text{C}_{10}\text{H}_{17}\text{COOCH}_3$. A colourless liquid, b.p. 223°C ., with a camphor-like odour. Used in the manufacture of perfumes and as a plasticizer.

boron B. Element. A.W. 10.811. At. No. 5. A brown amorphous powder, r.d. 2.37, or yellow crystals, r.d. 2.34; m.p. 2300°C . It occurs as borax and boric acid. Used for hardening steel and for producing enamels and glasses. As boron absorbs slow neutrons, it is used in steel alloys for making control rods in nuclear reactors.

boron carbide B_4C . A very hard black crystalline substance, m.p. 2450°C ., used as an abrasive and as a moderator in nuclear reactors.

boron chamber An ionization chamber lined with boron or boron compounds or filled with boron trifluoride gas. Used in boron counter tubes.

boron counter tubes A counter tube containing a boron chamber used for counting neutrons. The counting pulse results from particles emitted when neutrons react with the ^{10}B isotope.

bort Boart. Impure or discoloured diamond; useless as a gem, it is as hard as pure diamond and is used for drills, cutting tools, etc.

Bosch process An industrial process for the manufacture of hydrogen. Water gas, a mixture of carbon monoxide and hydrogen, is mixed with steam and passed over a heated catalyst. The steam reacts chemically with the carbon monoxide to give carbon dioxide, CO_2 , and hydrogen. The CO_2 is then removed by dissolving it in water under pressure. Named after C. Bosch (1874-1940).

Bose-Einstein statistics The branch of statistical mechanics used with systems of identical particles having the property that the wave function remains unchanged if any two particles are interchanged. See bosons. Named after S. N. Bose (1894-1974) and Albert Einstein (1879-1955).

BOSONS

bosons Particles that conform to *Bose-Einstein statistics*, such as *photons* and *mesons*, whose numbers are not conserved in particle interactions. Bosons have *integral spin* (0, 1, 2). See Appendix, Table 6.

botany The scientific study of plants.

boundary layer The layer of *fluid* closest to a body over which the fluid is flowing; owing to the *force of adhesion* between the body and the fluid the boundary layer has a reduced rate of flow.

Bourdon gauge A *pressure gauge* for steam boilers, etc. It depends on the tendency of a partly flattened curved tube to straighten out when under internal pressure.

Boyle's law At a constant *temperature*, the *volume* of a given quantity of any gas is inversely proportional to the *pressure* upon the gas; i.e.

$$V \propto 1/P, \text{ or } PV = \text{constant.}$$

It is only true for a *perfect gas*. Named after Robert Boyle (1627-91). See also *gas laws*.

Bragg's law When a *beam of X-rays*, of *wavelength* λ , strikes a *crystal surface*, the maximum intensity of the reflected ray occurs when $\sin \theta = n\lambda/2d$. Where d is the distance separating the layers of the *atoms* or *ions* in the crystal, θ is the *complement* of the angle of *incidence*, and n is an *integer*. Named after W. H. Bragg (1862-1942) and W. L. Bragg (born 1890).

brake horsepower The *horsepower* of an engine measured by the degree of resistance offered by a brake; it represents the useful horsepower that the engine can develop.

branched chain A chain of carbon atoms in an organic molecule, in which the main chain has one or more branches.

branching (phys.) The occurrence of more than one *radioactive disintegration* scheme for a particular *nuclide*.

brass A large class of *alloys*, consisting principally of copper and zinc.

breeder reactor A *nuclear reactor* that produces the same kind of *fissile* material as it burns. E.g. a reactor using plutonium as a fuel can produce more plutonium than it uses by conversion of uranium-238.

Bremsstrahlung (German, meaning 'brake radiation'). *X-rays* emitted when an *electron* strikes a positively charged *nucleus*; it results from the direct conversion of *kinetic energy* into *electromagnetic radiation*.

brewing The making of beer. *Malt* is ground and mixed with water. In the resulting 'mash', chemical changes take place, the chief of which is the conversion of *starch* into *maltose*, forming a sweetish liquid known as wort. This is boiled with the addition of hops. After cooling and removal of *solids*, *yeast* is added and *fermentation* occurs.

Brewster's law The tangent of the angle of *polarization* is numerically equal to the *refractive index* of the reflecting medium when the

polarization is a maximum. Named after David Brewster (1781-1868).

brimstone Sulphur fused into blocks or rolls.

Brinell test A test for the hardness of *metals*. A ball of chrome *steel*, or other hard material, of standard size, is pressed by a heavy load into the surface of the metal, and the diameter of the depression is measured. The Brinell Number is the ratio of the load in *kilograms* to the *area* of the depression in square millimetres. Named after J. A. Brinell (1849-1925).

Britannia metal An *alloy* of variable composition, containing 80%-90% tin, with some antimony and copper, and sometimes also zinc and lead.

British thermal unit The quantity of *heat* required to raise the *temperature* of 1 lb of *water* through 1° Fahrenheit; equal to 251.997 *calories* or 1055.06 *joules*.

bromate A salt of *bromic acid*.

bromic acid HBrO_3 . A *compound* that is only stable in *dilute solution*. Formed by the action of *sulphuric acid* on barium bromate, and used as an *oxidizing agent*.

bromide Salt of *hydrobromic acid*, HBr ; *binary compound* with bromine. 'Bromide' of pharmacy is *potassium bromide*, KBr .

bromide paper Photographic paper containing *silver bromide*, AgBr .

bromination A reaction in which one or more bromine atoms are substituted for hydrogen atoms in an organic molecule.

bromine Br. Element. A.W. 79.909. At. No. 35. A dark red fuming *liquid* with a choking, irritating smell, r.d. 3.12, b.p. 58.8°C. It occurs as magnesium bromide, MgBr_2 , in *bittern* from *sea-water*, in the *Stassfurt deposits*, in marine plants and animals, and in some inland lakes. Used as a *disinfectant* and in the manufacture of some *organic compounds*. Compounds are used in *photography* and *medicine*.

bromoform CHBr_3 . A colourless *liquid*, m.p. 8.3°C., b.p. 149.5°C., used in *organic synthesis*.

bronze 1. A class of *alloys* of copper and tin. 2. A copper alloy containing no tin, e.g. *aluminium bronze* is an alloy of copper and aluminium.

Brownian movement Erratic random movements performed by microscopic particles in a *disperse phase*; e.g. particles in suspension in a *liquid*, or *smoke* particles in air. Caused by the continuous irregular bombardment of the particles by the *molecules* of the surrounding medium. Named after Robert Brown (1773-1858).

Brunswick green See *copper oxide chloride*.

brush discharge The discharge of *electricity* from sharp points on a *conductor*. The surface density (i.e. quantity of electricity per unit area) is greatest at sharp points; the high charge at such points causes a displacement of the charge on the air particles near the

BUBBLE CHAMBER

points, and hence an attraction to the points. On reaching the points, the particles acquire some of the charge on the points and are repelled. This causes a stream of charged air particles to leave the vicinity of the points.

bubble chamber An instrument for making the tracks of ionizing particles visible as a row of bubbles in a *liquid*. The liquid is heated to slightly above its *boiling point* and maintained under *pressure* to prevent boiling. Immediately before the passage of the particles the pressure is reduced, the ionized particles then act as centres for the formation of small *vapour* bubbles, which can be photographed to give a record of the tracks of the particles.

Büchner funnel A funnel, usually of *porcelain*, with a flat circular base perforated with small holes. Used for filtering by suction. Named after E. Büchner (1860-1917).

buffer solution A *solution* the *hydrogen ion concentration* of which, and hence the acidity or alkalinity, is practically unchanged by dilution. It also resists a change of *pH* on the addition of *acid* or *alkali*.

bulk density The *density* of a powder or of a porous or granular substance, calculated for unit volume of the substance including the pores or spaces between the grains; it is generally less than the true density of the material.

bulk modulus *Elastic modulus* applied to a body having uniform *stress* distributed over the whole of its surface. Its value is given by the expression pV/v where p = intensity of stress, V = original *volume* of the body, and v = change in volume.

Bunsen burner A burner for *coal-gas*, used in laboratories. It consists of a metal tube with an adjustable air-valve for burning a mixture of gas and air. Named after R. W. Bunsen (1811-99).

Bunsen cell A *primary cell* in which the *anode* consists of zinc and is immersed in dilute *sulphuric acid*, and the *cathode* consists of carbon immersed in concentrated *nitric acid*.

buoyancy The upward thrust exerted upon a body immersed in a *fluid*; equal to the *weight* of the fluid displaced. (See *Archimedes' principle*). Thus a body weighs less when weighed in water, the apparent loss in weight being equal to the weight of the water displaced. For accurate weighing of bodies in air, a small allowance has to be made to correct for the buoyancy of the body.

burette A graduated glass tube with a tap, for measuring the volume of *liquid* run out from it. Used in *volumetric analysis*.

burning See *combustion*.

burnt alum A white porous mass of *anhydrous* potassium aluminium sulphate, $K_2SO_4 \cdot Al_2(SO_4)_3$, obtained by heating *alum*.

butadiene $CH_2:CH:CH:CH_2$. A *gas* used in the manufacture of synthetic *rubbers*. See *styrene-butadiene rubber*; *nitrile rubber*; *stereoregular rubbers*.

- butanal** Butyraldehyde. $\text{CH}_3(\text{CH}_2)_2\text{CHO}$. A colourless inflammable liquid, b.p. 75.7°C ., used in the *plastics* and *rubber* industries.
- butane** C_4H_{10} . A hydrocarbon of the *alkane* series. Gas at ordinary temperatures. B.p. -0.5°C . Used in the manufacture of *synthetic rubber* and as a *fuel* (e.g. in cylinders under pressure under the trade name Butagas*).
- butanedione** Diacetyl, biacetyl. $\text{CH}_3\text{COCOCH}_3$. A yellow liquid, b.p. 89°C ., that occurs in butter. Used as a flavour.
- butanol** Butyl alcohol. $\text{C}_4\text{H}_9\text{OH}$. A liquid that exists in four *isomeric* forms. 1-butanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, has a b.p. 117.5°C . and is used as a *solvent*.
- butanone** Ethyl methyl ketone. $\text{C}_2\text{H}_5\text{COCH}_3$. An inflammable liquid, b.p. 79.6°C ., used as a *solvent* and in the manufacture of *plastics*.
- butter of antimony** Antimony trichloride. SbCl_3 . A white crystalline substance, m.p. 73°C .
- butyl** The *univalent alkyl radical* C_4H_9- .
- butyl rubber** A synthetic *rubber*; copolymer (see *polymerization*) of iso-butylene and sufficient *isoprene* (2%-3%) to enable vulcanization to be effected. Owing to its low *permeability* to *gases*, butyl rubber is used in the manufacture of tyre inner tubes.
- butyric acid** Butanoic acid. $\text{C}_3\text{H}_7\text{COOH}$. A liquid with a rancid odour, b.p. 163.5°C ., which occurs in rancid butter. Used in the form of its *esters* as a flavouring.
- butyryl** The *univalent radical* $\text{CH}_3(\text{CH}_2)_2\text{CO}-$.
- bypass capacitor** Bypass condenser. A *capacitor* that provides a path of low *impedance* over a certain range of *frequencies*.
- by-product** A substance obtained incidentally during the manufacture of some other substance. Often as important as the manufactured substance itself. E.g. the by-products of *coal-gas* manufacture include *ammonia*, *coal-tar*, and *coke*.
- byte** A single unit of information handled by a *computer*; usually 8 *bits*.

cacodyl The dimethylarsino group, $(\text{CH}_3)_2\text{As}-$, derived from *arsine*.

cadmium sulphide CdS . A yellow *insoluble* powder, used as a *pigment* known as 'cadmium yellow'. In the impure natural form it is known as 'greenockite'.

cadmium Cd . Element. A.W. 112.40. At. No. 48. A soft silvery-white *metal*, r.d. 8.642, m.p. 320.9°C . It occurs together with zinc. Used in the manufacture of *fusible alloys* and for *electroplating*. As cadmium is a good absorber of *neutrons* it is used in the manufacture of *control rods* for *nuclear reactors*.

cadmium cell Standard *primary cell*. See *Weston cell*.

caesium Cesium. Cs . Element. A.W. 132.905. At. No. 55. A highly reactive silvery-white *metal* resembling sodium in its physical and chemical properties. r.d. 1.87, m.p. 28.5°C . *Compounds* are very rare. Used in *photoelectric cells* and as a *catalyst*.

caesium clock A device used in the *SI unit* definition of the *second*. It is based on the energy difference between two states of the caesium nucleus in a magnetic field. This energy difference corresponds to a *frequency* of 9 192 631 770 *hertz*. A beam of caesium atoms is split into the two components by a non-uniform magnetic field. Nuclei in the lower state are irradiated in a cavity by radio-frequency radiation at the difference frequency. Some are excited to the higher frequency by absorbing this radiation. By reanalyzing the mixture of atoms and using a feedback system, the r-f oscillator can be locked to the difference frequency with an accuracy of one part in 10^{13} . It thus constitutes an extremely accurate clock.

caffeine Theine. $\text{C}_8\text{H}_{10}\text{O}_2\text{N}_4$. A white crystalline *purine*, m.p. 237°C ., that occurs in tea-leaves, coffee-beans, and other plant material. It has a powerful action on the heart and is used in medicine.

calamine A zinc mineral, originally either *zinc carbonate*, ZnCO_3 , or *zinc silicate*, $2\text{ZnO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$. In British usage calamine refers to the carbonate but in American usage it refers to the silicate. Also used for a skin preparation consisting of *zinc oxide* with $\frac{1}{2}\%$ *ferric oxide*.

calciferol Vitamin D_2 . $\text{C}_{28}\text{H}_{43}\text{OH}$. A crystalline *unsaturated alcohol*, m.p. 115°C ., formed by the action of *ultraviolet radiation* on *ergosterol*. See *vitamins*. It controls the deposition of calcium compounds in the body; deficiency causes rickets.

calcination Strong heating; conversion of *metals* into their *oxides* by heating in air.

calcite Calcspar. Natural crystalline *calcium carbonate*, CaCO_3 .

CALCIUM SILICATES

- calcium** Ca. Element. A.W. 40.08. At. No. 20. A soft white *metal* that tarnishes rapidly in air; r.d. 1.55, m.p. 845°C. *Compounds* are very abundant, widely distributed, and essential to life. It occurs as *calcium carbonate*, CaCO_3 (*limestone*, *marble*, and *chalk*) and *calcium sulphate*, CaSO_4 (*gypsum*, *anhydrite*); it is an essential constituent of bones and teeth. Compounds are of great industrial importance; e.g. *lime*.
- calcium carbide** Carbide. CaC_2 . A greyish solid, colourless when pure; prepared by heating *calcium oxide* with carbon in an electric furnace. It reacts with water to give *acetylene*.
- calcium carbonate** CaCO_3 . A white *insoluble* solid; it occurs naturally as *chalk*, *limestone*, *marble*, and *calcite*. Used in the manufacture of *lime* and *cement*.
- calcium chloride** CaCl_2 . A white *deliquescent* substance, m.p. 772°C., obtained by reacting *calcium carbonate* with *hydrochloric acid*. Used as a drying agent and preservative.
- calcium cyanamide** Cyanamide, Nitrolime. CaCN_2 . A black crystalline powder made by heating *calcium carbide*, CaC_2 , in nitrogen at 1000°C. Used as a *fertilizer* and converted by water in the soil into *ammonia*.
- calcium cyclamate** $(\text{C}_6\text{H}_{11}\text{NHSO}_3)_2\text{Ca} \cdot 2\text{H}_2\text{O}$. A white crystalline *soluble* powder, formerly used as a sweetening agent in soft drinks, but its excessive consumption has been shown to be undesirable and it has therefore been banned.
- calcium fluoride** See *fluorspar*.
- calcium hydroxide** *Slaked lime*. $\text{Ca}(\text{OH})_2$. A white crystalline powder, obtained by the action of water on *calcium oxide*, used in *mortars*, *plaster*, and *cement*.
- calcium nitrate** A white *deliquescent* solid, m.p. 561°C., used in the manufacture of *fertilizers*, *fireworks*, *matches*, and *explosives*.
- calcium oxide** *Quicklime*. CaO . A white solid, m.p. 2580°C., made by heating *calcium carbonate* (*limestone*) in lime-kilns. It combines with water to form *calcium hydroxide* (*slaked lime*); used in *cements* and *mortars* and in the manufacture of *calcium compounds*.
- calcium oxychloride** Calcium hypochlorite. See *bleaching powder*.
- calcium phosphate** There are several *phosphates* of calcium that occur in rocks and animal bones. Tricalcium diorthophosphate, $\text{Ca}_3(\text{PO}_4)_2$, is a white *amorphous* powder, m.p. 1670°C. (see *bone ash*). It is converted to the more *soluble* calcium hydrogen orthophosphate, $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$, a *deliquescent* crystalline substance, which is the main constituent of *superphosphate*. See also *octacalcium phosphate*.
- calcium silicates** A range of compounds, including native *minerals*, composed of *calcium oxide* (CaO) and *silica* (SiO_2) in various molecular ratios; e.g. calcium metasilicate, CaSiO_3 , and calcium orthosilicate, Ca_2SiO_4 . Various calcium silicate phases are formed

CALCIUM SULPHATE

in *glass* and *cement* during the manufacture of these materials. See *silicates*.

calcium sulphate CaSO_4 . A white *salt* that is slightly soluble in water. It exists in a number of crystalline forms, including anhydrite (CaSO_4) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The latter is converted to *plaster of Paris* (calcium sulphate hemihydrate) on heating.

calcium sulphide CaS . A colourless crystalline substance, having an odour of bad eggs, used in the manufacture of luminous *paints* and in cosmetics.

calculus A powerful method of solving numerous mathematical problems. It is divided into two main parts, *differential calculus* and *integral calculus*.

calibration The *graduation* of an instrument to enable measurements in definite *units* to be made with it; thus the arbitrary scale of a *galvanometer* may be calibrated in *amperes*, thereby converting the instrument into an *ammeter* for measuring *electric current*.

caliche Impure natural *sodium nitrate* NaNO_3 , found in Chile.

californium Cf. *Transuranic element*. At. No. 98. The most stable isotope, $^{251}_{98}\text{Cf}$, has a *half-life* of 800 years.

callipers Calipers. An instrument for measuring the distance between two points, especially on a curved surface; e.g. for measuring the internal and external diameters of tubes.

calomel See *mercurous chloride*.

calomel electrode A *half cell* consisting of a mercury electrode covered with *calomel* (mercury I chloride) and a solution of mercury in *potassium chloride*. It is used as a standard electrode, its potential being 0.2415 volt at 25°C . with respect to a *hydrogen electrode*.

calorescence Absorption of *light* radiations by a surface, their conversion into *heat*, and the consequent emission of *heat radiation*.

calorie Unit of quantity of *heat*. The amount of heat required to raise the *temperature* of 1 g of *water* through 1°C . The 15° calorie is defined as the amount of heat required to raise the temperature of 1 g of water from 14.5°C . to 15.5°C . This calorie is equal to 4.1855 *joules*. The International Table Calorie is defined as 4.1868 *joules*. The joule is the *SI unit of heat*.

calorie, large Kilogram-calorie. 1000 *calories*. Written Calorie or kcalorie. Used for quoting energy values of foods.

calorific value of a fuel. The quantity of *heat* produced by a given *mass* of the *fuel* on complete *combustion*. Expressed in *joules per kilogram (SI units)*, *calories per gram (c.g.s. units)* or *British Thermal Units per pound (f.p.s units)*. Determined by the *bomb calorimeter*.

calorimeter Instrument for determining quantities of *heat* evolved, absorbed, or transferred. In its simplest form consists of an open cylindrical vessel of copper or other substance of known *heat capacity*.

calx 1. The powdery *oxide* of a *metal* formed when an *ore* or a *mineral* is roasted. **2.** Quicklime (see *calcium oxide*).

camera, photographic A device for obtaining photographs or exposing cinematic film, either coloured or black and white. A camera consists essentially of a *light-proof* box with a *lens* at one end and a light-sensitive film or plate at the other. An 'exposure' is made by opening a 'shutter' over the lens for a predetermined period during which an image of the object to be photographed is thrown upon the light-sensitive film. Focusing is carried out by varying the distance of the lens from the film by a suitable device. The amount of light that enters the camera, in order to obtain a correctly exposed photograph, is determined by the amount of light available (either sunlight or artificial light), the 'speed' of the film, the *aperture* of the lens (see *f number*), and the shutter speed. In the simplest cameras the shutter speed and aperture are fixed, so that satisfactory photographs can only be obtained in bright sunlight. In more expensive cameras the aperture can be controlled by a variable *iris* and several separate shutter speeds are provided. In some modern cameras the iris is controlled by the current from a built-in *photoelectric cell* (*exposure meter*), which measures the light available. Thus for given film and shutter speeds the camera automatically takes a correctly exposed photograph. In cinematic cameras the opening of the shutter is mechanically synchronized with the passage of the film through the camera so that, at normal speeds, between 16 and 24 frames are exposed every second. See also *photography*.

camera, television The part of a *television* system that converts optical images into electrical signals. It consists of an optical *lens* system similar to that used in a photographic *camera*, the image from which is projected into a 'camera tube'. The camera tube comprises a *photosensitive mosaic* that is scanned by an *electron* beam housed in an evacuated glass tube. The output signals of the camera tube are usually pre-amplified within the body of the camera.

camphor $C_{10}H_{16}O$. A white crystalline *solid* with a characteristic smell, m.p. $178^{\circ}C$. It occurs in the camphor tree and is used in the manufacture of *celluloid* and in other industries.

Canada balsam A yellowish *liquid* derived from fir trees with a *refractive index* similar to that of *glass*. Used for mounting microscopic slides and as an *adhesive* for optical instruments.

canal rays Positively charged *ions* produced during the *discharge* of electricity in gases, driven to the *cathode* by the applied *potential difference* and allowed to pass through canals bored in the cathode.

candela New candle. The *SI unit* of *luminous intensity*. Defined as the luminous intensity, in the perpendicular direction, of a surface of $1/600\,000$ square *metre* of a *black body* at the *temperature* of

CANDLEPOWER

- freezing platinum under a pressure of $101\,325\text{ N m}^{-2}$. The candela now replaces the *international candle*. Symbol *cd*.
- candlepower** of a light source, in a given direction, is the *luminous intensity* of the source in that direction expressed in terms of the *candela*. Formerly expressed in terms of the *international candle*.
- candle wax** Usually either *paraffin wax* or *stearine*.
- cane sugar** Sucrose, saccharose. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A *disaccharide* obtained from the sugar-cane. Chemically identical with *beet sugar*.
- Canton's phosphorus** Impure *calcium sulphide*, CaS , having the property of *phosphorescence* after exposure to *light*. Used in *luminous paints*.
- caoutchouc** Raw *rubber*.
- capacitance** Electrical capacity. *C*. The property of a system of electrical *conductors* and *insulators* that enables it to store *electric charge* when a *potential difference* exists between the conductors. Measured by the charge that must be communicated to such a system to raise its potential by one unit. The *SI unit* of capacitance is the *farad*.
- capacitor** Electrical condenser. A system of electrical *conductors* and *insulators*, the principal characteristic of which is its *capacitance*. The simplest form consists of two parallel *metal* plates separated by a layer of air or some other insulating material, such as *mica* (see *dielectric*). The capacitance, *C*, of such a parallel plate capacitor is given by:
- $$C = A\epsilon/d$$
- where ϵ is the *permittivity*, in *farad per metre*, *A* the area of plate, and *d* the distance between them.
- capillary action** Capillarity. A general term for phenomena observed in *liquids* due to unbalanced inter-molecular attraction at the liquid boundary; e.g. the rise or depression of liquids in narrow tubes, the formation of films, drops, bubbles, etc.
- capillary tube** A tube of small internal diameter.
- capric acid** See *decanoic acid*.
- caproic acid** See *hexanoic acid*.
- caprylic acid** See *octanoic acid*.
- capture** A process by which an atomic or nuclear system acquires an additional particle, e.g. the capture of *electrons* by *ions* or of *neutrons* by *nuclei*. 'Radiative capture' is a nuclear capture process that results in the emission of *gamma rays* only.
- caramel** (chem.) A brown substance of complex composition, formed by the action of *heat* on *sugar*.
- carat** 1. A measure of weight of *diamonds* and other gems; formerly 3.17 grains (0.2053 g), now standardized as the international carat, 0.200 g. 2. A measure of *fineness* of gold, expressed as parts of gold

in 24 parts of the *alloy*. Thus, 24 carat gold is pure gold, 18 carat gold contains 18 parts in 24 or has a fineness of 750.

carbamide See *urea*.

carbamoyl The *univalent radical* $\text{NH}_2\text{CO}-$.

carbide *Binary compound* of carbon; loose term for *calcium carbide*.

carbinol Former name for *methanol*. It was also used in naming other *alcohols*, regarding them as derivatives of methanol. E.g. *ethanol*, $\text{CH}_3\text{CH}_2\text{OH}$, where CH_3 replaces one H atom in methanol, was called methylcarbinol.

carbocyclic compounds A class of organic compounds containing closed rings of carbon atoms in their molecules. It includes *alicyclic* (e.g. *cyclohexane*) and *aromatic* (e.g. *benzene*) compounds.

carbohydrases *Enzymes* that hydrolyze (see *hydrolysis*) *carbohydrates*; e.g. *amylase*, *lactase*, and *maltase*.

carbohydrates A large group of *organic compounds* composed of carbon, hydrogen, and oxygen only, with the general formula $\text{C}_x(\text{H}_2\text{O})_y$. Comprises *monosaccharides*, *disaccharides* (both *sugars*), and *polysaccharides* (*starch* and *cellulose*). Carbohydrates play an essential part in the *metabolism* of all living *organisms*, starch being the principal form in which *energy* is stored and cellulose being the principal structural material of plants.

carbolic acid See *phenol*.

carbon C. Element. A.W. 12.011, At. No. 6, m.p. 3550°C . It occurs in several allotropic forms (see *allotropy*) including *diamond* (r.d. 3.51) and *graphite* (r.d. 2.25); and as *amorphous carbon* (r.d. 1.8-2.1) in the forms of *lamp-black*, *gas carbon*, etc. Compounds occur as the metallic *carbonates*, *carbon dioxide* in the air, and an enormous number of *organic compounds*. Owing to its *valence* of four, carbon atoms are able to unite with each other to form the very large *molecules* upon which life is based. See *carbon cycle* (bio.). Animals obtain their energy by the *oxidation* of carbon compounds eaten as food. See also *radiocarbon dating*.

carbonado A black, discoloured, or impure variety of *diamond*, useless as a gem but very hard and used for drills, etc.

carbonate A salt of *carbonic acid*, H_2CO_3 .

carbonation Treatment with *carbon dioxide*, usually for the formation of *carbonates*.

carbon black A finely divided soot-like form of *carbon*, produced by *pyrolysis* or by incomplete *combustion* from carbon-rich materials, such as *mineral oils*, *acetylene*, or *natural gas*. Used mainly as a reinforcing *pigment* in rubber, and also as a black pigment in inks, plastics, etc.

carbon cycle (bio.) The circulation of carbon (as *carbon dioxide*) between living *organisms* and the *atmosphere*. Carbon dioxide is built into complex carbon compounds by plants during *photosynthesis*; animals obtain their carbon atoms by feeding on plants or

CARBON CYCLE

other animals; during *respiration*, and by decay after death, some of this carbon is returned to the atmosphere in the form of carbon dioxide.

carbon cycle (phys.) A cycle of six consecutive *nuclear reactions* resulting in the formation of a *helium* nucleus from four *protons*. The carbon nuclei with which the cycle starts are reformed at the end and therefore act as a *catalyst*. The *energy* liberated by the carbon cycle is thought to be the main source of energy in a large class of *stars*.

carbon dioxide Carbonic acid gas. CO_2 . A colourless gas with a faint tingling smell and taste. It occurs in the *atmosphere* as a result of the *oxidation* of carbon and carbon *compounds*. Atmospheric carbon dioxide is the source of carbon for plants (see *photosynthesis* and *carbon cycle* (bio.)). It forms a solid at -78.5°C . at atmospheric pressure, and is used as a *refrigerant* in this form as *dry ice*, for the preservation of frozen foods, etc. As carbon dioxide gas is heavier than air and does not support *combustion*, it is used in *fire extinguishers*.

carbon disulphide Carbon bisulphide. CS_2 . A colourless inflammable liquid, b.p. 46°C ., with a high *refractive index*. It is made by heating sulphur with carbon or with *methane* at high temperatures. Used as a *solvent* in various industrial processes, in manufacture of viscose rayon, and as a *pesticide*.

carbon fibre A material consisting of black silky threads of pure carbon that can be made stronger and stiffer than any other material of the same *weight*. Typical fibres are about $7\text{ }\mu\text{m}$ in diameter and have a *tensile strength* of up to 220 000 kg per square cm. They are made by heat-treating organic textile fibres in such a way that the side chains are stripped off, leaving only the carbon backbone. This backbone is subjected to further mechanical and heat treatment so that the crystallites are pulled into orientation along the axis of the fibre. They are used to reinforce a matrix of *resin*, *ceramic*, or *metal* with up to 600 000 fibres per square centimetre of cross-section and in this form make a valuable constructional material where strength is required at high *temperatures*, such as in components for jet engines and *rockets*.

carbonic acid H_2CO_3 . A very weak *acid* probably formed in small amounts when *carbon dioxide* dissolves in *water*. It is never obtained pure as it breaks up almost completely into carbon dioxide and water when obtained in a chemical reaction. It gives rise to two series of *salts*, the *carbonates* and *bicarbonates* (now called 'hydrogen carbonates').

carbonization See *destructive distillation*.

carbon monoxide CO . A colourless, almost odourless gas that is very poisonous when breathed, as it combines with the *haemoglobin* of the *blood* to form bright red carboxyhaemoglobin. This is chemically

stable, and thus the haemoglobin is no longer available to carry oxygen. It burns with a bright blue *flame* to form *carbon dioxide*. It is formed during the incomplete *combustion* of *coke*, *charcoal*, and other carbonaceous *fuels*; it occurs in *coal-gas* and in the exhaust fumes of motor engines. Used in the *Mond process* for nickel and in organic synthesis.

carbon tetrachloride CCl_4 . A heavy colourless *liquid* with a sweetish smell, b.p. 76.8°C . Used as a non-inflammable *solvent* and in *fire extinguishers* (*pyrene*).

carbonyl The *divalent* group $=\text{CO}$, characteristic of *aldehydes* and *ketones*.

carbonyl chloride See *phosgene*.

carbonyls *Compounds of metals with carbon monoxide*; e.g. nickel carbonyl, $\text{Ni}(\text{CO})_4$.

carborundum *Silicon carbide*. SiC . A dark crystalline *solid*, nearly as hard as *diamond*, used as an *abrasive* and as a *refractory* material. Made by heating *silica*, SiO_2 , with carbon in an electric furnace.

carboxyl group The *univalent* group, $-\text{COOH}$, characteristic of the organic *carboxylic acids*.

carboxylic acids *Organic acids* containing one or more *carboxyl groups* in the molecule; e.g. *acetic acid*, CH_3COOH ; *phthalic acid*, $\text{C}_6\text{H}_4(\text{COOH})_2$. They form *salts* with *bases* and *esters* with *alcohols*. See also *fatty acid*.

carburettor A device in the *internal-combustion* petrol engine for mixing air with *petrol vapour* prior to explosion.

carcinogen A substance capable of producing cancer (*carcinoma*).

carnallite Natural potassium magnesium chloride, $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, found in the *Stassfurt deposits*. An important source of potassium *salts*.

carnosine $\text{C}_9\text{H}_{14}\text{N}_4\text{O}_2$. An *optically active* crystalline *dipeptide*, m.p. 260°C ., found in muscle *tissue*.

carnotite Uranium potassium *vanadate* of variable composition. *Ore* of uranium.

Carnot's cycle An ideal reversible cycle of operations for the working substance of a heat engine. The four steps in the cycle are: (a) *isothermal* expansion, the substance taking in *heat* and doing *work*; (b) *adiabatic* expansion, without heat change, external work done; (c) *isothermal* compression, heat given out, work done on the substance by external forces; (d) *adiabatic* compression, no heat change, work done on the substance. Named after N. L. S. Carnot (1796-1832).

Carnot's principle The *efficiency* of any reversible heat engine depends only on the *temperature* range through which it works and not upon the properties of any material substance. If all the heat is taken up at *absolute temperature* T_1 and all given out at *absolute temperature* T_2 (as in *Carnot's cycle*), the efficiency is $(T_1 - T_2)/T_1$.

CARO'S ACID

Caro's acid, H_2SO_5 . See *persulphuric acids*.

carotene $\text{C}_{40}\text{H}_{56}$. A yellow *unsaturated hydrocarbon* present in carrots and butter. It is converted into vitamin A (see *vitamins*) in the animal *organism*. Carotene acts as a photosynthetic pigment (see *photosynthesis*) in plant *cells* that lack *chlorophyll*.

carrier (chem.) 1. A substance assisting a *chemical reaction* by combining with part or all of the *molecule* of one of the reacting substances to form a *compound* that is then easily decomposed again by the other reacting substance; the carrier is thus left unchanged. See *catalyst*. 2. An inactive substance used to transport a *radioisotope* in *radioactive tracing*. A radioisotope is said to be 'carrier-free' if it can be used without a carrier. 3. Sometimes called carrier gas. The gas used to carry the sample through the column in *gas chromatography*.

carrier (phys.) The mobile *electrons* or *holes* that carry charges in a *semiconductor*.

carrier wave A continuous *electromagnetic radiation*, of constant *amplitude* and *frequency*, emitted by a *radio* transmitter. By *modulation* of the carrier wave, oscillating *electric currents* caused by *sounds* at the transmitting end are conveyed by it to the receiver.

carron oil A mixture of *vegetable oil* (olive or cotton-seed) with *lime-water*. Used as an application for burns.

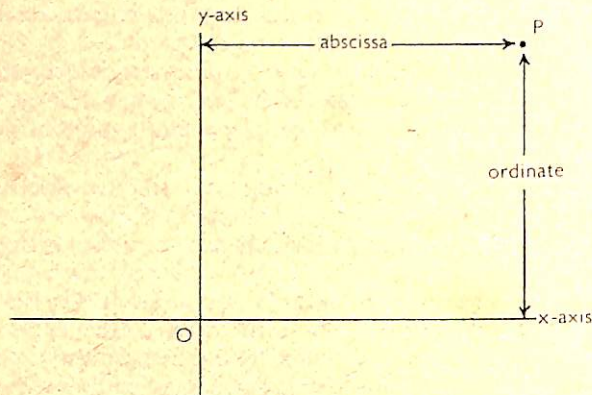


Figure 5.

Cartesian coordinates A system for locating a point, P, in a *plane* by specifying its distance from two *axes* at right angles to each other, which intersect at a point O, called the *origin*. The distance from the horizontal or x-axis is called the *ordinate* of P; the distance from the y-axis is called the *abscissa*. See Fig. 5. The system may also be used to locate a point in space by using a third, z-axis. Named after R. Descartes (1596-1650).

CASSEGRANIAN TELESCOPE

carvacrol $(\text{CH}_3)_2\text{CH}.\text{C}_6\text{H}_3\text{CH}_3\text{OH}$. A colourless oily *liquid*, b.p. 237.7°C ., with a mint-like odour. Used as a *disinfectant*, and in perfume.

carvone Carvol. $\text{C}_{10}\text{H}_{14}\text{O}$. An optically active liquid *ketone* related to the *terpenes*, b.p. 231°C ., found in *essential oils* and used in flavours and perfumes.

cascade liquefier An apparatus used for liquefying air, oxygen, etc. A gas cannot be liquefied until it is brought to a *temperature* below its *critical temperature*. In the cascade liquefier the critical temperature of the gas is reached step by step, using a series of gases having successively lower *boiling points*. The first of these, which can be liquefied by compression at ordinary temperatures, is allowed to evaporate under reduced *pressure*; this produces a temperature below the critical temperature of the second gas, which can then be liquefied. This is similarly allowed to evaporate, and the step is repeated until finally the desired liquefaction is reached.

cascade process A process used in the separation of *isotopes*. It consists of a series of stages connected so that the separation produced by one stage is multiplied in subsequent stages. In a 'simple cascade' the enriched fraction is fed to the succeeding stage and the depleted fraction to the preceding stage.

cascade shower See *shower*.

casein The main *protein* of milk. A pale yellow *solid* obtained from milk by the addition of *acid* ('acid casein'), by controlled souring ('self-soured casein'), or by curdling with *rennet* ('rennet casein'). Used in paper-coating, *paints*, *adhesives*, *plastics*, and for making artificial textile fibres.

caseinogen British term for *casein* before precipitation. The American terms are casein before precipitation, and paracasein after.

CASSEGRANIAN TELESCOPE

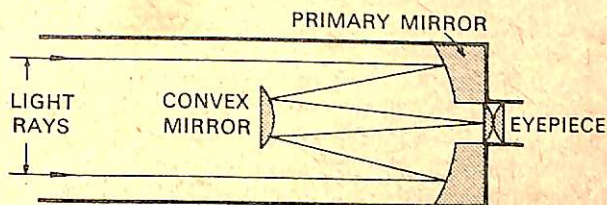


Figure 6.

Cassegrainian telescope A form of astronomical reflecting *telescope* in which a hole in the centre of the primary mirror allows the light to pass through it to the eye-piece or the photographic plate. See Fig. 6.

CASSIOPEIUM

cassiopeium See *lutetium*.

cassiterite SnO_2 . Natural *stannic oxide*. It is the principal ore of tin.

cast iron Pig-iron. Impure, brittle form of iron, such as produced in the *blast furnace*. It contains from 2%-4.5% carbon in the form of *cementite* and usually also some manganese, phosphorus, silicon, and sulphur. Generally not used direct, but converted into *steel* or *wrought iron*.

castor oil A *vegetable oil* extracted from the seed of the castor plant, consisting of *glyceryl esters of fatty acids*; the predominant acid (about 85%) being *ricinoleic acid*, $\text{C}_{17}\text{H}_{32}(\text{OH}).\text{COOH}$. Used in the *paint* and varnish industry as well as medically as a laxative.

catabolism Katabolism. The part of *metabolism* dealing with the chemical *decomposition* of complex substances into simple ones, with a release of *energy*.

catalase An *enzyme* that decomposes *hydrogen peroxide*.

catalysis The alteration of the rate at which a *chemical reaction* proceeds, by the introduction of a substance (*catalyst*) that remains unchanged at the end of the reaction. Small quantities of the catalyst are usually sufficient to bring the action about or to increase its rate substantially.

catalyst A substance that alters the rate at which a *chemical reaction* occurs, but is itself unchanged at the end of the reaction. Catalysts are widely used in the chemical industry; *metals* in a finely divided state, and *oxides* of metals, are frequently used. The *enzymes* are organic catalysts produced by living *cells*.

catalytic cracking The use of a *catalyst* to bring about the *cracking* of high boiling mineral oils.

cataphoresis See *electrophoresis*.

catechol See *pyrocatechol*.

catenary A curve formed by a chain or string hanging from two fixed points. Equation, $y = \cosh x/k$, where k is the distance between the *vertex* of the curve and the *origin*.

catenation The process of chain formation in organic molecules.

catenoid The surface generated by rotating a *catenary* about its vertical axis.

catetometer A *telescope* mounted on a graduated vertical pillar along which it can move. The instrument is used for measuring lengths and displacements at a distance of a few feet.

cathode Negative *electrode*. Negatively charged *conductor* in *electrolysis* and in *thermionic valves*. See *discharge in gases*.

cathode-ray oscilloscope CRO. An instrument based upon a *cathode-ray tube*, which provides a visible image of one or more rapidly varying electrical quantities. Also used as an indicator in a *radar* system.

cathode rays A stream of *electrons* emitted from the negatively charged *electrode* or *cathode* when an electric discharge takes place in a

vacuum tube, i.e. a tube containing a gas at very low pressure. See *discharge in gases*.

cathode-ray tube CRT. A vacuum tube that allows the direct observation of the behaviour of *cathode rays*. It consists essentially of an *electron gun* producing a beam of *electrons* that, after passing between horizontal and vertical deflection plates, falls upon a luminescent screen: the position of the beam can be observed by the *luminescence* produced upon the screen. *Electric potentials* applied to the deflection plates are used to control the position of the beam, and its movement across the screen, in any desired manner. Used as the picture tube in *television* receivers and in *cathode-ray oscilloscopes*.

catholyte The *electrolyte* near the *cathode* during *electrolysis*.

cation Positively charged *ion*; an ion that, during *electrolysis*, is attracted towards the negatively charged *cathode*.

cationic dyes See *basic dyes*.

causality The relating of causes to the effects that they produce. Many contemporary physicists believe that no coherent causal description can be given of events that occur on the sub-atomic scale.

caustic Corrosive towards organic matter (but not applied to *acids*). E.g. *caustic soda*.

caustic (phys.) Parallel rays of *light* falling on a *concave* spherical mirror do not form a point image at the *focus* (see *mirrors, spherical*). Instead, there is a region of maximum concentration of the rays forming a curve or surface of revolution, called a *caustic*, the *apex* or *cusps* of which is at the focus of the mirror. A similar *caustic* occurs in the image formed by a *convex lens* receiving parallel light. Such a curve may be seen on the surface of a liquid in a cup, formed by the reflection of light upon the curved wall of the cup.

caustic alkali *Sodium* or *potassium hydroxide*.

caustic potash *Potassium hydroxide*, KOH.

caustic soda *Sodium hydroxide*, NaOH.

cavitation The formation of cavities in *fluids* when the pressure drops as a result of high *velocity*, in accordance with *Bernoulli's theorem*. These vapour-filled cavities collapse when they are carried to regions of higher pressure and the resulting impact pressure can cause pitting of such parts as propellers.

celestial equator (astr.) The circle in which the *plane* of the Earth's *equator* meets the *celestial sphere*.

celestial mechanics The branch of *astronomy* concerned with the motions of celestial bodies or systems under the influence of *gravitational fields*.

celestial sphere (astr.) The imaginary *sphere* to the inner surface of which the heavenly bodies appear to be attached; the observer is situated at the centre of the sphere. See Fig. 2 under *azimuth*.

CELESTINE

celestine Natural crystalline strontium sulphate, SrSO_4 , mined as a source of strontium.

cell (bio.) The unit of life. All living *organisms* are composed of discrete, membrane-bounded units, which usually comprise two distinct forms of *protoplasm*: the *nucleus* and the *cytoplasm*. The former contains the *nucleic acids* responsible for organizing the synthesis of the cell's *enzymes* and for controlling the characteristics of its progeny, while the latter contains the enzyme systems that control the cell's *metabolism* and manufacture its constituents. Many *microorganisms* (e.g. *bacteria*, protozoa, etc.) consist of only one cell, whereas a man consists of some million million cells.

cell (phys.) A device for producing an *electric current* by chemical action. See *accumulator*; *primary cell*.

celluloid A *thermoplastic* material made from *cellulose nitrate* and *camphor*.

cellulose A *polysaccharide* that occurs widely in nature in fibrous form as the structural tissue in the cell walls of plants. Its *macromolecules* consist of long unbranched chains of *glucose* units. It is obtained from wood pulp, cotton, and other plant sources; used in the manufacture of *paper*, *rayon*, *plastics*, and *explosives*.

cellulose acetate An *ester* obtained by the action of *acetic anhydride* on *cellulose*. A white *solid*, used in the manufacture of *rayon* and *plastics*.

cellulose nitrate Nitrocellulose. *Nitric acid ester* of *cellulose*. A range of *compounds* formed by treatment of cellulose with a mixture of *nitric* and *sulphuric acids*; properties depend on the extent to which the *hydroxyl groups* of the cellulose are esterified (see *esterification*). Used in the manufacture of *plastics*, *lacquers*, and *explosives*.

Celsius temperature Centigrade temperature. *Temperature* measured on a scale originally devised by Anders Celsius (1701-44) in which the *melting point* of ice was 0° and the *boiling point* of water was 100° . This definition has been superseded by the *International Practical Temperature Scale* of 1968, which is expressed in both *kelvins* and degrees Celsius. The unit for both means of expressing temperature is the kelvin, and temperature differences may be expressed in kelvins even when using Celsius temperatures. The relation between the Kelvin temperature (T) and the Celsius temperature (t) is given by: $T = t + 273.15$.

celtium See *hafnium*.

cement 1. Any bonding material. 2. Portland cement and allied cements are made from materials containing *lime*, *alumina*, and *silica* (e.g. *limestone* and *clay*), which are heated strongly in a kiln to form clinker (consisting mainly of calcium *silicates* and *aluminates*). The finely ground clinker undergoes complex *hydration* processes when mixed with water, setting and hardening to a stone-like material.

cementation An early process for *steel* manufacture. Bars of *wrought iron* were heated for several days in *charcoal* at red heat.

cementite Iron carbide. Fe_2C . A hard, brittle *compound* that is responsible for the brittleness of *cast iron* and is present in *steel*.

centi- Prefix denoting one hundredth of, in *metric units*. Symbol *c*, e.g. $\text{cm} = 0.01$ metre.

central processing unit Central processor. See *C.P.U.*

centre of curvature of a spherical mirror. The centre of the sphere of which the *mirror* forms a part.

centre of gravity of a body is the fixed point through which the *resultant force* of *gravity* always passes, irrespective of the position of the body. This is identical to the *centre of mass* in a uniform *gravitational field*.

centre of mass The point at which the *mass* of a body may be considered to be concentrated. The point from which the sum of the *moments of inertia* of all the component particles of a body is zero.

centrifugal force The outward *force* acting on a body rotating in a *circle* round a central point. The centripetal force is the radial force imposed by the constraining system, necessary to keep the body moving in its circular path. The centrifugal and centripetal forces are equal and opposite. The centrifugal force acting on a body of mass m moving in a circle radius r , with a *velocity* v is mv^2/r .

centrifuge An apparatus for separating particles from a *suspension*. Balanced tubes containing the suspension are attached to the opposite ends of arms rotating rapidly about a central point; by *centrifugal force* the suspended particles are forced outwards, and collect at the bottoms of the tubes. See also *ultracentrifuge*.

centrigade temperature See *Celsius temperature*.

centripetal force See *centrifugal force*.

ceramic Pertaining to products or industries involving the use of *clay* or other *silicates*.

cerargyrite See *horn silver*.

Cerenkov (Cherenkov) radiation *Light* emitted when charged particles pass through a transparent medium at a *velocity* greater than the *velocity of light* in that medium. Named after P. A. Cerenkov (born 1904).

Ceres The largest of the *asteroids*.

ceresin Hard, brittle *paraffin wax* with a *melting point* in the range of 70° – 100°C . Used as a substitute for *beeswax* in *paints* and *polishes*.

ceric Containing *tetravalent cerium*.

cerium *Ce*. Element. A.W. 140.12. At. No. 58. A steel-grey soft *metal*, r.d. 6.7, m.p. 795°C . It occurs in several rare minerals, e.g. *monazite* sand, and is used in *pyrophoric alloys* for lighter 'flints'; *compounds* are used in the manufacture of *gas mantles* and in *glass* polishing.

cerium dioxide *Ceria*. CeO_2 . A white crystalline powder, m.p. 2600°C ., used in *glass* polishing.

CERMET

cermet Ceramet. Abbreviation of CER(A)mic and METal. A very hard mixture of a *ceramic* substance and *sintered* metal, used where resistance to high *temperature*, *corrosion*, and abrasion is required.

cerous Containing *trivalent* cerium.

cetane $C_{16}H_{34}$. See *hexadecane*.

cetane number A measure of the ignition characteristics of a diesel fuel by comparison with a range of mixtures, in which *cetane* is given a value of 100 and α -methyl-naphthalene is 0.

cetyl alcohol See *hexadecanol*.

c.g.s. system Centimetre-gram-second system. A system of physical *units* derived from the centimetre, *gram* mass and the *second*. E.g. *velocities* in c.g.s. units may be measured in centimetres per second. Now superseded for scientific purposes by the *SI units*.

chabasite A natural *zeolite*, calcium aluminium silicate. See *ion exchange*.

chain reaction In general, any self-sustaining molecular or *nuclear reaction*, the products of which contribute to the propagation of the reaction. In particular a fission chain reaction is a process in which one nuclear transformation is capable of initiating a chain of similar transformations. For example, when *nuclear fission* occurs in a uranium-235 *nucleus*, between 2 and 3 *neutrons* are emitted, each of which is capable of causing the fission of further uranium-235 nuclei. The chain reaction so created is the basis of the atomic bomb (see *nuclear weapons*) and the *nuclear reactor*. If the average number of *transformations* directly caused by one transformation is less than one, the reaction is said to be convergent or *subcritical*; if it is equal to one, the reaction is self-sustained or critical; if it exceeds one, the reaction is divergent or *supercritical*.

chalcedony A variety of natural impure *silica*, SiO_2 , that has a fibrous structure and a waxy lustre. Used for ornaments.

chalcocite Copper glance. Natural copper sulphide, Cu_2S . It occurs in veins with other copper ores.

chalcogens The elements of group VIA of the *periodic table*: oxygen, sulphur, selenium, tellurium, and polonium.

chalcopyrite Copper pyrites. A natural sulphide of copper and iron, $(Cu,Fe)S_2$; the most abundant ore of copper.

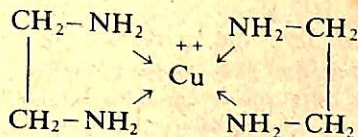
chalk Natural *calcium carbonate*, $CaCO_3$, formed from the shells of minute marine *organisms*. Blackboard chalk sticks are *calcium sulphate*, $CaSO_4$.

chalcones Physiologically active substances produced within *tissues* that appear to control the *mitosis* of the *cells* of the specific tissues that produce them.

chalybeate Chalybite. Natural ferrous carbonate, $FeCO_3$.

change of state (phys.) The conversion of a substance from one of the *physical states of matter* (*solid*, *liquid*, or *gas*) into another. E.g. the melting of ice.

- channel** In *telecommunications*, a path for the transmission of electrical signals, often specified by its *frequency band*. In *information theory*, a path or route along which information may flow or be stored.
- channel capacity** The number of signals per second that can be transmitted through a *channel*. Also, in *information theory*, the hypothetical limiting rate at which information could be communicated by a given channel, with the frequency of errors tending to zero.
- character** A unit of information as handled by *computers*, usually six *bits*.
- characteristic** (math.) The *integral* or whole-number part of a *logarithm*.
- charcoal** A general name for numerous varieties of *carbon*, usually impure; generally made by heating vegetable or animal substances with exclusion of air. Many forms are very porous and adsorb various materials readily. See *activated carbon*.
- charge, electric** See *electric charge*.
- Charles' law** At constant *pressure* all gases expand by $1/273$ of their *volume* at 0°C ., for each 1°C . rise in *temperature*; the volume of a fixed mass of gas at constant pressure is proportional to the *absolute temperature*. Named after J. A. C. Charles (1746-1823). See also *gas laws*.
- charm** A property of matter postulated to account for the characteristics of the *psi particle* (discovered in 1974). According to this hypothesis a fourth *quark* (and its antiquark) exists having the property called charm. The psi particle itself is not charmed as it consists only of a charmed quark and its antiquark, which give zero charm. However, other charmed *hadrons* are believed to exist and there is some experimental evidence to support the belief. Charm must be conserved in *strong interactions* and *electromagnetic interactions* but not in *weak interactions*.
- cheddite** Class of *explosives* containing *sodium* or *potassium chlorate* with *dinitrotoluene* and other organic substances.
- chelation** The formation of a closed ring of *atoms* by the attachment of *compounds* or *radicals* to a central *polyvalent metal ion* (occasionally non-metallic); usually due to the sharing of a *lone pair of electrons*, from oxygen or nitrogen atoms in the compounds or radicals, with the central ion, e.g. two *molecules* of ethylenediamine ($\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$) form a 'chelate ring' with a cupric ion as shown in the diagram.



Chelating agents are used for 'locking up' (sequestering) unwanted metal ions; for instance they are added to shampoos with the object of softening the water by locking up *ferric*, calcium, and magnesium ions. When used for this purpose they are called sequestering agents. Many tests for identifying metal ions depend on the formation of coloured *insoluble* chelates. *Chlorophyll* and *haemoglobin* are naturally occurring chelate compounds in which the central ions are magnesium and iron respectively.

chemical affinity See *affinity* and *free energy*.

chemical change A change in a substance involving an alteration in its chemical composition, due to an increase, decrease, or rearrangement of *atoms* within its *molecules*. See *equation, chemical*; *molecule*.

chemical combination, laws of Three laws defining the ways in which chemical *compounds* are formed:

Law of constant composition. A definite chemical compound always contains the same *elements* chemically combined in the same proportions by *weight*.

Law of multiple proportions. When two elements unite in more than one proportion, for a fixed *weight* of one element there is always a simple relationship with the weight of the other element present.

Law of combining weights (also termed the law of reciprocal proportions, law of equivalents). Elements combine in the ratio of their combining weights or *chemical equivalents*; or in some simple multiple or sub-multiple of that ratio.

chemical energy That part of the *energy* stored within an *atom* or *molecule* that can be released by a *chemical reaction*.

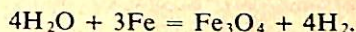
chemical engineering The design, operation, and manufacture of plant or machinery used in industrial chemical processes.

chemical equilibrium Many *chemical reactions* do not go to completion; in such cases a state of equilibrium or balance is reached when the original substances are reacting at the same rate as the new substances are reacting with each other to form the original substances. Thus, if two substances *A* and *B* react to form *C* and *D*, the state at equilibrium is denoted by the balanced equation

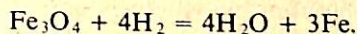


If one of the substances is removed, the system readjusts the equilibrium; thus, if *C* is constantly removed as soon as formed, more *A* and *B* react until the action is completed. An equilibrium reaction that could thus be made to complete itself in either direction is termed a *reversible reaction*. E.g. if *steam* is passed over red-hot iron, iron oxide and hydrogen are formed, the latter being

constantly removed by more steam which passes through; the reaction thus goes to completion according to the equation



If, however, hydrogen is passed over red-hot iron oxide, the reverse action takes place



If the reaction is allowed to proceed in an enclosed space, a state of equilibrium is reached, all four substances being present. See also *equilibrium constant*.

chemical equivalents Combining weights. The combining proportions of substances by *weight*, relative to hydrogen as a standard. The equivalent of an *element* is the number of grams of that element which will combine with or replace 1 g of hydrogen or 8 g of oxygen. The gram-equivalent, or equivalent weight, is the equivalent expressed in grams. The equivalent weight of an *acid* is the weight of the acid containing unit weight of replaceable *acidic hydrogen*. The equivalent weight of a *base* is the weight of the base required to neutralize the equivalent weight of an acid. The combining proportions of substances by weight are in the ratio of their equivalents, or in some simple multiple or sub-multiple of that ratio. For an element, the *atomic weight* is equal to the product of its equivalent and its *valence*. The gram-equivalent as a unit quantity of substance in chemical calculations has been replaced in *SI units* by the *mole*. E.g. 1 equivalent of H_2SO_4 equals 1 mole of $\frac{1}{2}\text{H}_2\text{SO}_4$.

chemical reaction The interaction of two or more substances, resulting in *chemical changes* in them.

chemiluminescence Cold flame. The evolution of *light* accompanied by some *heat* during a *chemical reaction*. See *luminescence*.

chemisorption See *adsorption*.

chemistry The study of the composition of substances, and of their effects upon one another. The main branches are *inorganic chemistry*, *organic chemistry*, and *physical chemistry*. See also *biochemistry*.

chemotherapy The treatment of disease by chemical substances that are toxic to the causative *microorganisms* or directly attack *neoplastic* growths.

chemurgy The study of chemical industrial processes based on organic substances of agricultural origin.

chert A natural form of silica, SiO_2 , resembling flint.

Chile saltpetre Impure *sodium nitrate*, NaNO_3 . It occurs in huge deposits in Chile.

china clay Kaolin. A pure natural form of *hydrated* aluminium silicate, $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$. On heating, it loses *water* and changes its chemical composition. Used for making *porcelain*.

CHINESE WHITE

Chinese white *Zinc oxide*, ZnO .

chirality The concept of 'handedness' (right- or left-handedness) applied to *stereoisomerism*. A geometrical figure representing the configuration of a *molecule* in space is said to have chirality if its image in a plane mirror cannot be made to coincide with it.

Chiron A minor planet, discovered in 1977 by Charles Kowal, that revolves around the Sun between the orbits of Saturn and Uranus.

chitin A complex organic substance, related to the *carbohydrates* but containing nitrogen. It forms an essential part of the shells of crustaceans and insects. Also found in some fungi.

chlor(o)acetic acids The following three substituted *acetic acids*: monochloroacetic acid, CH_2ClCOOH , which is a crystalline solid, m.p. 63°C .; dichloroacetic acid, CHCl_2COOH , a colourless *liquid*, m.p. 10°C ., b.p. $192-3^\circ\text{C}$.; trichloroacetic acid, CCl_3COOH , a *deliquescent* crystalline solid, m.p. 56.3°C . All forms are used in the manufacture of *dyes* and as wart removers. All are stronger acids than acetic acid itself.

chloracne A disfiguring skin disease that is caused by certain chlorinated aromatic hydrocarbons. It can result from contact, ingestion, or inhalation of the chemicals.

chloral Trichlorethanal. CCl_3CHO . A pungent colourless oily *liquid*, b.p. 97.7°C .

chloral hydrate $\text{CCl}_3\text{CH}(\text{OH})_2$. A white crystalline *solid*, m.p. 57°C . Prepared from *chloral* by the action of *water*. Used in medicine as a *hypnotic* and in the manufacture of *D.D.T.*

chloranil $\text{C}_6\text{Cl}_4\text{O}_2$. A yellow *insoluble* crystalline substance, m.p. 290°C ., used as a *fungicide* and in the manufacture of *dyes*.

chlorargyrite See *horn silver*.

chlorate A salt of *chloric acid*.

chloric acid HClO_3 . A hypothetical *acid* known only in *solution* or in the form of its salts, the *chlorates*.

chloride A salt of *hydrochloric acid*, HCl .

chloride of lime *Calcium oxychloride*, CaOCl_2 . See *bleaching powder*.

chlorination 1. The introduction of a chlorine atom into a compound by *substitution* or by an *addition reaction*. 2. The treatment of drinking water with chlorine or a chlorine compound, such as *sodium hypochlorite* or *bleaching powder*.

chlorine Cl . Element. A.W. 35.453. At. No. 17. A greenish-yellow poisonous gas with a choking irritating smell. The first poison gas to be used in warfare (by Germany, Ypres, 1915). *Compounds* occur as common salt (*sodium chloride*), NaCl , in *sea-water* and as *rock salt*; and as *chlorides* of other *metals*. Manufactured almost entirely by the *electrolysis* of brine. Used in the manufacture of *bleaching powder*, *disinfectants*, *hydrochloric acid* and many organic compounds. Also used as a *germicide* in drinking-water.

- chlorite** 1. A salt of *chlorous acid*. 2. A group of *mineral silicates* of aluminium, iron, and magnesium.
- chloroacetone** $\text{CH}_3\text{COCH}_2\text{Cl}$. A colourless poisonous *liquid*, b.p. 119°C ., used in the manufacture of *insecticides* and in organic synthesis.
- chlorobenzene** Phenyl chloride. $\text{C}_6\text{H}_5\text{Cl}$. A colourless inflammable *liquid*, b.p. 132°C ., used as a *solvent* and in the synthesis of *drugs*.
- chloroethane** Ethyl chloride. $\text{C}_2\text{H}_5\text{Cl}$. A colourless poisonous gas, used as a refrigerant and as an alkylating agent.
- chloroethene** See *vinyl chloride*.
- chloroform** CHCl_3 . A *volatile* colourless heavy *liquid* with a powerful sweet smell, b.p. 61°C . Made from *acetone*, *acetaldehyde*, or *ethanol* by the action of *bleaching powder*, or by the action of chlorine on *methane*, CH_4 . Used as an *anaesthetic* and industrial *solvent*.
- chlorohydrins** *Organic compounds* containing a *chlorine* atom and a *hydroxyl* group attached to adjacent *carbon* atoms in a *hydrocarbon* molecule; they are formed by *addition* of *hypochlorous acid* at the *double bond* to *alkenes*.
- chloromethane** Methyl chloride. CH_3Cl . A colourless poisonous gas, used as a *refrigerant* and as a *methylation* agent.
- Chloromycetin*** Chloramphenicol. $\text{C}_{11}\text{H}_{12}\text{Cl}_2\text{N}_2\text{O}_5$. A colourless crystalline *antibiotic*, active against certain *bacteria* and certain *viruses*.
- chlorophenol** $\text{ClC}_6\text{H}_4\text{OH}$. A substituted *phenol* that exists in three *isomeric* forms. The *ortho-* form has m.p. 8.7°C . and b.p. 175°C ., the *meta-* form has m.p. 32.8°C ., and the *para-* form has m.p. 43°C . All forms are used in the manufacture of *dyes*.
- chlorophyll** A green *pigment* found in plants, which absorbs *energy* from sunlight, enabling them to build up *carbohydrates* from atmospheric *carbon dioxide* and *water* by *photosynthesis*. It consists of a mixture of two pigments, chlorophyll-a ($\text{C}_{55}\text{H}_{72}\text{O}_5\text{N}_4\text{Mg}$) and chlorophyll-b ($\text{C}_{55}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$).
- chloropicrin** CCl_3NO_2 . An oily *liquid*, b.p. 112°C . Highly poisonous and chemically active. Used as a *disinfectant* and *fungicide*.
- chloroplatinic acid** Platinum chloride solution. $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$. A brown *hygroscopic soluble* substance, m.p. 60°C ., used in *platinizing glass* and *ceramics*.
- chloroprene** $\text{CH}_2=\text{CH}.\text{CCl}=\text{CH}_2$. A colourless *liquid*, b.p. 59.4°C ., used in the manufacture of *neoprene synthetic rubber*.
- chloroquinol** Chlorohydroquinone. $\text{C}_6\text{H}_3\text{Cl}(\text{OH})_2$. A white crystalline *soluble solid* that can exist in six *isomeric* forms. Used as a *photographic developer* and in organic synthesis.
- chlorous acid** HClO_2 . A hypothetical *acid* known only in *solution*, or in the form of its *salts*.
- choke** Choking coil. A coil of low *resistance* and high *inductance* used

CHOKE-DAMP

in electrical circuits to pass *direct currents* whilst suppressing *alternating currents*.

choke-damp See *after-damp*.

cholesteric crystals *Liquid crystals* in which the molecules are arranged in layers, with their axes parallel and in the planes of the layers. See also *smetic crystals*; *nematic crystals*.

cholesterol $C_{27}H_{45}OH$. A white waxy *sterol* present in the *tissues* of the human body, in which it performs a number of vital functions. Its excessive production in man is suspected of being a contributory cause of coronary thrombosis.

choline $OH.C_2H_4N(CH_3)_3OH$. An *organic base* that is a constituent of some *fats* and of egg yolk. It is a member of the *vitamin B* complex.

chondrite A type of stony meteorite (see *meteor*) that contains the small round masses of *olivine* or *pyroxene* known as chondrules.

chord (math.) A straight line joining two points on a curve. See *circle*.

chromate A salt of *chromic acid*.

chromatic aberration See *aberration*, *chromatic*.

chromatids The two identical strands into which a *chromosome* splits during *cell* reproduction.

chromatography A method of chemical analysis in which a mobile phase, carrying the mixture to be analysed, is caused to move in contact with a selectively absorbent stationary phase. The mobile phase may be a solution of a mixture of compounds in a suitably inert solvent or it may be a mixture of compounds in a vapour diluted with an inert carrier gas. The stationary phase may be an absorbent (active) solid or a liquid supported on an absorbent solid: it is characterized by its ability to retain the components of the mixture to different degrees. During the progress of the mobile phase in contact with the stationary phase, the components of the mixture become separated and can be identified; in some cases they can be determined quantitatively.

When the mobile phase is a gas and the stationary phase is a liquid on a solid support the process is known as 'gas-liquid chromatography' (see *gas chromatography*, to which it is often shortened). This is one of the most powerful methods of analysis. When the stationary phase is an active solid, the process is known as 'gas-solid chromatography'.

When the mobile phase is a liquid, it can be applied to a column of the active solid (see *column chromatography*) or to a thin layer of the solid on a plate (see *thin-layer chromatography*). Filter paper can also be used as the stationary phase (see *paper chromatography*). The last two processes provide particularly powerful methods of chemical investigation.

chromatron Chromoscope. A type of *cathode ray tube* that has four screens; used as a colour picture-tube in *television*.

- chrome alum** See *chromic potassium sulphate*.
- chrome iron ore** Chrome ironstone, chromite, ferrous chromite. $\text{FeO} \cdot \text{Cr}_2\text{O}_3$. A source of chromium *metal* and its *compounds*.
- chrome red** Basic lead chromate, $\text{PbO} \cdot \text{PbCrO}_4$. Used as a *pigment* in *paints*.
- chrome yellow** Lead chromate, PbCrO_4 . Used as a *pigment*.
- chromic** Containing *trivalent* chromium.
- chromic acid** H_2CrO_4 . A hypothetical *acid* known only in *solution* or in the form of its *salts*.
- chromic potassium sulphate** Chrome alum. $\text{K}_2\text{SO}_4 \cdot \text{Cr}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$. A dark purple crystalline *soluble salt*, used in *dyes*, *calico printing* and *tanning*.
- chromite** 1. See *chrome iron ore*. 2. A salt of *bivalent* chromium.
- chromium** Cr. Element. A.W. 51.996. At. No. 24. A hard white *metal* resembling *iron*; r.d. 7.18, m.p. 1857°C . It occurs as *chrome iron ore* and is extracted by reducing the *oxide* with aluminium (see *Goldschmidt process*). Used in the manufacture of *stainless steel* and for *chromium plating*.
- chromium plating** The deposition of a thin resistant film of chromium *metal* by *electrolysis* from a bath containing a *solution* of *chromic acid*.
- chromium steel** *Steel* containing varying amounts of chromium; strong and tough, used for tools, etc.
- chromium trioxide** Chromic anhydride. CrO_3 . A red *deliquescent* crystalline substance, m.p. 196°C ., that is a strong *oxidizing agent*.
- chromophore** Any chemical group, such as the *azo group*, that causes a *compound* to have a distinctive colour.
- chromosomes** Thread-like bodies that occur in the *nuclei* of living *cells*, the *molecules* of which carry the *genetic code*. They consist of *nucleoproteins*, the *nucleic acid* being *DNA*. The unit of genetic information is the *gene* (see also *cistron* and *operon*) and each chromosome may be regarded as comprising a number of genes. Chromosomes occur in pairs in *somatic cells*, each species being characterized by the different number of chromosomes that its cells contain (Man has 46 chromosomes per cell).
- chromosphere** The layer of the *Sun's* atmosphere surrounding the *photosphere*, which is visible during a total *eclipse*. The chromosphere is several thousand miles thick and has an estimated temperature of 20 000 K.
- chromous** Containing *bivalent* chromium.
- chromyl** The *bivalent radical* $\text{CrO}_2 =$, containing *sexivalent* chromium; e.g. in chromyl chloride, CrO_2Cl_2 .
- chronograph** An accurate time-recording instrument.
- chronometer** An accurate clock, especially one used on a ship in navigation.

CHRONON

chronon A hypothetical particle of time defined as the ratio of the diameter of an *electron* to the *velocity of light*: i.e. the time taken for light to traverse an electron. Approximately 10^{-24} second.

Chronotron* A device that measures the time between two events, by measuring the positions on a transmission line of pulses initiated by the events.

ciment fondu See *bauxite cement*.

cinchonidine $C_{19}H_{22}N_2O$. A white crystalline *alkaloid*, m.p. 207.2°C ., used as a substitute for *quinine*. One of its *isomers*, cinchonine, m.p. 265°C ., is also used for this purpose.

cineole $C_{10}H_{18}O$. A colourless oily *liquid terpene*, b.p. 176.4°C ., with an odour of *camphor*. Found in certain *essential oils* and used in perfumes and medicine.

cinnabar Natural *mercuric sulphide*, HgS . A bright red crystalline *solid*, r.d. 8.1. It is the principal ore of mercury.

cinnamic acid $C_6H_5\text{CH}:\text{CHCOOH}$. A white crystalline *insoluble* substance the *cis-form* of which has a m.p. 42°C ., and the *trans-form* has a m.p. 135°C . Used in perfumes.

cinnamyl group The *univalent* group $C_6H_5\text{CH}:\text{CH}.\text{CH}_2-$, derived from *cinnamic acid*.

circle (math.) A plane figure contained by a line, called the *circumference*, which is everywhere equidistant from a fixed point within it, called the *centre*. The distance from the centre to the circumference is the *radius*; a straight line joining any two points on the circumference is a *chord*; a chord passing through the centre, equal in length to twice the radius, is a *diameter*; any portion of the circumference is an *arc*; a portion cut off by a chord is a *segment*; a portion cut off by two radii is a *sector*. The ratio of the circumference to the diameter, denoted by π ('pi') = $3.14159\dots$ (approx. $22/7$). Length of circumference = $2\pi r$; area = πr^2 , where r = radius.

circuit, electrical The complete path traversed by an *electric current*.

circularly polarized light *Light* that can be resolved into two vibrations lying in *planes* at right angles, of equal *amplitude* and *frequency* and differing in *phase* by 90° . The *electric vector* of the wave describes, at any point in the path of the wave, a *circle* about the direction of propagation of the light as axis. See also *polarization of light*.

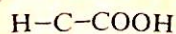
circular measure of angles. The measurement of *angles* in *radians*.

circular mil A unit of area. The area of a *circle* whose diameter is 0.001 inch, i.e. 0.785×10^{-6} sq in. Used in measuring the cross-section of fine wire.

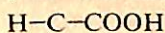
circumference See *circle*.

cis-trans isomerism A form of *isomerism* associated with compounds containing a *double bond*. Like groups in such compounds may be either on the same side of the plane of the double bond (*cis-form*)

or on opposite sides (*trans*-form). E.g. *maleic acid* and *fumaric acid* (see chemical formulae) are respectively *cis*- and *trans*-forms.



Maleic acid



Fumaric acid

See also *stereoisomerism*.

cistron The functional unit of genetic information, taking into account the distribution of abnormal (mutant) *genes* among pairs of *chromosomes*, and the way in which an abnormal gene in one chromosome may be compensated for by a normal gene either in the same chromosome (*cis*-configuration) or its pair (*trans*-configuration).

citrate A salt or ester of *citric acid*.

citric acid $\text{C}_6\text{H}_8\text{O}_7$. A white crystalline *soluble* organic *tribasic acid*, m.p. 153°C . It has a sour taste, and occurs as the free acid in lemons (6%) and other sour fruits. Used in the preparation of effervescent salts.

citric acid cycle Krebs cycle. A complex cycle of *enzyme*-controlled biochemical reactions, which occur within living *cells*, as a result of which *pyruvic acid* is broken down into *carbon dioxide* and *energy*. The citric acid cycle is a most important clearing-house of metabolic intermediates, since it deals with the final stages of the *oxidation* of *carbohydrates* and *fats* and is also involved in the synthesis of some *amino acids*.

citronellal $\text{C}_9\text{H}_{17}\text{CHO}$. A colourless *liquid aldehyde* existing in several *isomeric* forms, b.p. $205-8^\circ\text{C}$., with a lemon-like odour. Used as a flavouring and in the manufacture of perfume.

citronellol $\text{C}_9\text{H}_{17}\text{CH}_2\text{OH}$. A colourless *liquid alcohol* existing in several *isomeric* forms, b.p. 110°C ., used in the manufacture of perfumes.

cladding (phys.) The covering of a *fuel element* in a *nuclear reactor* by a thin layer of another *metal*, to prevent corrosion by the *coolant* and the escape of *fission products*.

Clark cell A standard *primary cell*, used as a standard of *E.M.F.*, that gives 1.4328 volts at 15°C . It consists of a zinc *amalgam anode* and a mercury *cathode*, both immersed in a *saturated solution* of zinc *sulphate*.

classical physics *Physics* prior to the *quantum theory* (or in some senses prior to the theory of *relativity*).

clathrate compounds Chemical *compounds* formed not by the action of *valence bonds*, but by 'molecular imprisonment', the combined *molecules* being held together mechanically by virtue of their configuration in space.

Claude process A process for producing *liquid air*, based on the cooling that results from the *adiabatic expansion* of a gas that is performing

external work. Air under pressure is divided into two separate channels. The first channel leads to a compressor, where the air performs external work by driving the compressor. The cool air so produced is used to reduce the temperature of the compressed air from the second channel in a counter-current *heat exchanger*.

clays Finely-divided *rock* materials whose component *minerals* are various *silicates*, mainly of *magnesium* and *aluminium*.

cleavage The manner of breaking of a crystalline substance, so that more or less smooth surfaces are formed.

clinical thermometer See *thermometer, clinical*.

clotting The formation of *solid* deposits or clots in *liquids*, often due to the *coagulation* of *soluble proteins* dissolved in the liquid. E.g. the clotting of *blood*.

cloud chamber (phys.) Wilson cloud chamber. An apparatus for making the tracks of ionizing particles visible as a row of droplets. It consists of a chamber filled with a saturated *vapour* and fitted with a piston to enable the vapour to be expanded *adiabatically*. This causes sudden cooling and supersaturation of the vapour. In this state, a beam of particles passing through the chamber creates a stream of *ions* along its path. The vapour forms liquid droplets on the ions, thus producing a visible track.

cloud point The temperature at which a *homogeneous liquid* becomes cloudy or turbid, owing to separation into two *phases*, when cooled under specified conditions.

Clusius column A device for separating gaseous *isotopes*. It consists of a high column with a central heated wire. As a result of *thermal diffusion* the lighter isotope collects at the top of the tube.

cluster (astr.) An aggregation of *stars* that move together. A *globular cluster* is an aggregation of stars in a roughly spherical arrangement.

coagulation of proteins When *solutions* of water-soluble *proteins* (*albumens*) are heated, the protein becomes 'denatured' at a definite *temperature*; it then becomes *insoluble* and either remains in *suspension* or is precipitated as a clot or curd. Other types of proteins, e.g. *globulins*, may be denatured and coagulated by *heat*, or by the addition of *acids* or *alkalis*. A denatured protein cannot be easily reconverted into the original *compound* (see *denature*).

coal A material, occurring in large underground deposits, consisting of carbon and various carbon *compounds*. Formed by the *decomposition* of vegetable matter during periods of many millions of years. The main types of coal are: *peat*, *lignite*, ordinary or *bituminous* coal, and *anthracite*.

coal-gas Fuel gas manufactured by the *destructive distillation* of *coal* in closed iron *retorts*; often supplemented with *water-gas* or *natural gas*. Composition by *volume* (average values): hydrogen 50%, *methane* 30%, *carbon monoxide*, 8%, other *hydrocarbons* 4%, nitrogen, *carbon dioxide*, and oxygen 8%.

coal-gas by-products Amongst the valuable substances obtained during the manufacture of coal-gas are *coke*, *coal-tar*, *ammonia*, *sulphuric acid*, and *pitch*.

coal-tar A thick black oily *liquid* obtained as a by-product of coal-gas manufacture. *Distillation* and purification yields, amongst other valuable products: *benzene*, C_6H_6 ; *toluene*, $C_6H_5CH_3$; *xylene*, $C_6H_4(CH_3)_2$; *phenol*, C_6H_5OH ; *naphthalene*, $C_{10}H_8$; *cresol*, $CH_3C_6H_4OH$, and *anthracene*, $C_{14}H_{10}$. *Pitch* is left as a residue.

coaxial Having a common axis. Coaxial cable consists of a central conducting wire and a concentric cylindrical conductor, the space between the two being filled with a *dielectric*, such as *polythene*. The outer conductor is normally connected to earth. Its main use is to transmit high-frequency power or signals from one place to another with minimum energy loss.

cobalt Co. Element. A.W. 58.9332. At. No. 27. A hard silvery-white magnetic *metal* resembling iron. R.d. 8.9, m.p. $1480^\circ C$. Occurs combined with sulphur and with arsenic. Extracted by converting the ore into the *oxide* and reducing with aluminium, or with carbon in an electric furnace. Used in many *alloys*; compounds used to produce a blue colour in *glass* and *ceramics*.

cobaltic Containing *trivalent* cobalt, e.g. cobaltic chloride, $CoCl_3$.

cobaltous Containing *divalent* cobalt, e.g. cobaltous chloride, $CoCl_2$.

cobalt steel *Steel* containing cobalt, and often other *metals* such as tungsten, chromium, and vanadium. The addition of cobalt results in greater hardness and brittleness, improves the cutting power of *high-speed-steel* tools, and alters the magnetic properties.

cocaine $C_{17}H_{21}O_4N$. A white crystalline *alkaloid* that occurs in the coca plant, m.p. $98^\circ C$. It is used as a local *anaesthetic* and is a dangerous habit-forming drug.

coccus A globular or spherical-shaped *bacterium*.

cochineal A natural red dyestuff obtained from the dried body of the *Coccus cacti* insect.

Cockcroft-Walton generator or accelerator A high voltage *direct current accelerator* used for accelerating nuclear particles (particularly *protons*). The DC voltage is obtained by multiplying a low AC voltage by an arrangement of *rectifiers* and *capacitors*.

codeine $C_{18}H_{21}O_3N$. A white crystalline *alkaloid*, m.p. $158^\circ C$., obtained by methylation of *morphine*. Used in medicine (often in the form of its *phosphate*) as an *analgesic*, *hypnotic*, and in the treatment of coughs.

coefficient (math.) A number or other known *factor* written in front of an algebraic expression. E.g. in the expression $3x^4$, 3 is the coefficient of x^4 .

coefficient (phys.) A *factor* or multiplier that measures some specified property of a given substance, and is constant for that substance

COELOSTAT

- under given conditions. E.g. coefficient of expansion. (See *expansion*, *coefficient of*, also *restitution*, *coefficient of*.)
- coelostat** A device used in conjunction with an astronomical telescope to follow the path of a celestial body and reflect its *light* into the telescope. It consists essentially of two mirrors, one movable and one fixed.
- coenzyme** A substance that plays an essential part in some reactions catalysed by *enzymes*, it often acts as a temporary *carrier* of an intermediate product of the reaction.
- coercive force** The strength of the *magnetic field* to which a *ferromagnetic substance* undergoing an *hysteresis cycle* must be subjected in order to *demagnetize* the substance completely. If the substance is magnetized to saturation during the cycle, the coercive force is called the *coercivity*. See Fig. 21 under *hysteresis cycle*.
- Coffey still** Apparatus for the *fractional distillation* of solutions of *ethanol* as obtained by *fermentation* on an industrial scale; the product is known as *rectified spirit*.
- coherent** A beam of *light*, or other *electromagnetic radiation*, is said to be coherent if its waves are in *phase*. See *laser*.
- coherent units** A system of *units* in which the *quotient* or *product* of any two units in the system yields the unit of the resultant quantity. E.g. when unit length is divided by unit time, the unit of *velocity* results. The basic units of a coherent system are arbitrarily defined physical quantities. All other units are obtained from these basic units by defining relations and are called 'derived units'. The coherent units now in scientific use are the *SI units*.
- coinage metals** The *metals* copper, silver, gold.
- coincidence circuit** Coincidence gate. An *electronic* circuit that produces an output only when two or more input signals arrive simultaneously, or within a specified time interval.
- coke** A greyish porous brittle *solid* containing about 80% carbon. Obtained as a residue in the manufacture of *coal-gas* ('gas coke'); also made specially in coke ovens, in which the *coal* is treated at lower *temperatures* than in gas manufacture.
- colchicine** $C_{22}H_{25}NO_6$. A yellow crystalline *alkaloid*, m.p. $156^{\circ}C.$, obtained from the autumn crocus, that interferes with the process of *mitosis* in such a way that it causes a doubling of the number of *chromosomes* in a *cell*. Used as an artificial method of obtaining new agricultural and horticultural varieties and in the treatment of gout.
- colcothar** Rouge, red iron oxide, *ferric oxide*, Fe_2O_3 . Used as a *pigment* and for polishing.
- collagen** A *protein* that is the major fibrous constituent of skin, tendon, ligament, and bone: it is, therefore, probably the most abundant protein in the animal kingdom. Collagen owes its unique properties not only to its chemical composition, but also to the physical

- arrangement of its individual *molecules*. The basic molecular *polypeptide* chain forms a left-handed *helix*, and three such helices are wrapped around each other to form a right-handed super-helix. On boiling with water collagen gives rise to *gelatin*.
- collargol** A powder containing *protein* material and finely divided silver; with water it forms a *colloidal solution* of silver.
- collector** The *electrode* in a *transistor* through which a primary flow of *carriers* leaves the inter-electrode region.
- colligative properties** Those properties of a substance (e.g. a *solution*) that depend only on the *concentration* of particles (*molecules* or *ions*) present and not upon their nature; e.g. *osmotic pressure*.
- collimator** 1. A tube containing a *convex achromatic lens* at one end and an adjustable slit at the other, the slit being at the focus of the lens. *Light* rays entering the slit thus leave the collimator as a parallel *beam*. 2. An arrangement of absorbers for limiting a beam of *radiation* to the required dimensions and angular spread in *radiology*. 3. A small fixed *telescope* attached to a larger one for the purpose of accurately setting the line of sight of the larger instrument.
- collision density** The number of collisions per unit volume per unit time that a given *neutron* flux makes when passing through *matter*.
- collodion** A *solution* of *cellulose nitrate* in a mixture of *alcohol* and *ether*.
- colloid** A substance present in *solution* in the *colloidal state*.
- colloidal metals** *Colloidal solutions* or *suspensions* of *metals*, the metal being distributed in the form of very small electrically charged particles. They are prepared by striking an electric arc between poles made of the metal, under water or by the chemical *reduction* of a *solution* of a *salt* of the metal. Used in medicine.
- colloidal solution** Sol. A *solution* in which the *solute* is present in the *colloidal state*. Common examples include solutions of *starch*, *albumen*, *colloidal metals*, etc. The *solvent* is termed the *dispersion medium* and the dissolved substance the *disperse phase*. Several types of colloidal solution are possible, depending upon whether the dispersion medium and the disperse phase are respectively *liquid* and *solid* (suspensoid sols), liquid and liquid (emulsoid sols), *gas* and solid, etc. If the disperse phase, when removed from solution by *evaporation* or coagulation, returns to the colloidal state on merely mixing with the dispersion medium, it is termed a reversible or *lyophilic colloid*, and the solution a reversible sol. If the disperse phase does not return to the colloidal state on simple mixing, it is termed an irreversible or *lyophobic colloid*.
- colloidal state** A system of particles in a *dispersion medium*, with properties distinct from those of a true *solution* because of the larger size of the particles. The presence of these particles, which are approximately 10^{-4} to 10^{-6} mm across, can often be detected by means of the *ultramicroscope*. As a result of the grouping of the

COLOGARITHM

molecules, a *solute* in the colloidal state cannot pass through a suitable *semipermeable membrane* and gives rise to negligible *osmotic pressure*, *depression of freezing point*, and *elevation of boiling point* effects. The molecular groups or particles of the solute carry a resultant *electric charge*, generally of the same sign for all the particles.

cologarithm The *logarithm* of the *reciprocal* of a number, expressed with a positive *mantissa*.

colophony See *rosin*.

colorimeter Apparatus used in *colorimetric analysis* for comparing intensities of *colour*. See also *tintometer*.

colorimetric analysis A form of *quantitative analysis* in which the quantity of a substance is estimated by comparing the intensity of *colour* produced by it with specific *reagents*, with the intensity of *colour* produced by a standard amount of the substance.

colour The visual sensation resulting from the impact of *light* of a particular *wavelength* on the cones of the retina of the eye. Light has three characteristics: *hue*, which is determined by its wavelength; *saturation*, the extent to which a colour departs from white; and *luminosity*, a measure of its brightness (for a light or other emitting source). If the source is a pigment, dye, etc., that reflects rather than emits light, this last characteristic is called *lightness*.

Coloured lights mix to form a different colour by an *additive process*. Pigments, dyes, etc., mix by a *subtractive process*.

colour temperature The *temperature* of a full radiator (see *black body radiation*) that would emit visible *radiation* of the same spectral distribution as the radiation from the *light* source under consideration.

colourtron A type of *cathode-ray tube*, used as a colour picture-tube in *television*, that has three *electron guns*, one for each *primary colour*.

colour vision *White light*, such as daylight, consists of a mixture of *electromagnetic radiations* of various *wavelengths* (see *spectrum colours*). A surface that reflects all of these will appear white; some surfaces, however, have the property of absorbing some of the radiations they receive, and reflecting the rest. Thus, a surface that absorbs all light radiations excepting those corresponding to green, will appear green by reflecting only those radiations. In the cases of colour seen by transmitted light, as in coloured *glass*, the glass absorbs all the radiations except those that are visible and pass through. See *surface colour*; *pigment colour*.

columbium Cb. See *niobium*.

column chromatography A form of *chromatography* in which the mobile phase is liquid and the stationary phase is *activated alumina*, or a similar substance, contained in a vertical glass column. The mixture is introduced at the top of the column and washed through

the stationary phase by a solvent. The components of the mixture are selectively adsorbed, forming coloured bands down the length of the column (if the components are coloured). The technique is used in laboratory preparations as well as in analysis, the eluate (see *elution*) being separated into fractions.

colza oil Rapeseed oil. Yellow oil obtained from the seeds of various Brassica plants. Used as an edible oil, illuminant, lubricant, and in the *quenching of steel*. 'Mineral colza' oil is a mixture of *paraffin hydrocarbons* with a boiling range of 250°-350°C.

coma 1. The nebulous patch of *light* that surrounds the *nucleus* of a *comet*. 2. An error of a *lens* or spherical *mirror* that causes a blurred *comet-like* image.

combination, laws of chemical See *chemical combination, laws of*.

combination (math.) A selection of a specified number of different objects from some larger specified number. The number of combinations of r different objects selected from n objects (i.e. the number of combinations of n objects taken r at a time) is denoted by the expression nC_r , and is equal to $n!/r!(n-r)!$. See also *factorial* and *permutation*.

combustion Burning. A *chemical reaction*, or complex of chemical reactions, in which a substance combines with oxygen producing *heat*, *light*, and *flame*. The combustion reactions that supply most of the *energy* required by human civilization involve the oxidation of *fossil fuels* in which carbon is converted into *carbon dioxide* and hydrogen is converted into *water* (*steam*).

comet A heavenly body, moving under the attraction of the *Sun* in an eccentric orbit. It consists of a hazy gaseous cloud (see *coma*) containing a brighter nucleus and a fainter tail. The nucleus is thought to consist of ice and dust particles.

command guidance A method of missile or *rocket* guidance in which computed information is transmitted to the missile and causes it to follow a directed flight path.

communication satellite See *satellite, artificial*.

commutative algebra The form of algebra in which the order of the terms is not important. For example, $a + b = b + a$ is a commutative equation.

commutator A device for altering or reversing the direction of an *electric current*; used in the *dynamo* to convert the *alternating current* into a direct one if required. It consists of a cylindrical assembly of insulated *conductors* each of which is connected to sections of the winding. Spring-mounted carbon brushes make contact with the conductors and thus carry the current to external circuits.

compass, magnetic In its simplest form a compass consists of a magnetized needle pivoted at its centre so that it is free to move in a horizontal plane. The effect of the Earth's *magnetic field* is to cause

COMPLEMENTARITY

the needle to set along the *magnetic meridian*. The needle is usually placed at the centre of a circular scale marked with the points of the compass. As such a compass is also affected by magnetic fields other than that of the Earth, for navigation the *gyro-compass* is used.

complementarity A term introduced into *quantum theory* by Niels Bohr (1885-1962), implying that evidence relating to atomic systems that has been obtained under different experimental conditions cannot necessarily be comprehended by one single model. Thus, for example, the wave model of the *electron* is complementary to the particle model.

complementary angles *Angles* together totalling 90° or one right angle.

complementary colours Pairs of *colours* that, when combined, give the effect of white. See *colour vision*.

complete radiation See *black body radiation*.

complex (chem.) Complex compound. The term originally derives from the recognition that compounds, which can exist as separate entities, may combine together by the formation of bonds (usually *coordinate bonds*) between atoms of the two components. The product is a complex compound, but the term now covers all analogous *coordination compounds*. Thus, a compound may form a *derivative (salt)* with a metal, but may also contain atoms that can coordinate with the metal in the product, so that the latter becomes a complex compound. See *complexons*; *porphyrins*; *chelation*.

complex number A complex number consists of two parts, 'real' and 'imaginary', and can be expressed in the form $x + iy$, where both x and y are real quantities and i is the square root of -1 , i.e. $i^2 = -1$. The real part of the complex number is 'x' and the imaginary part 'iy'. Such numbers obey the ordinary laws of *algebra* except that in *equations* containing them the real and imaginary parts are equated separately.

complexometric analysis A method of chemical analysis based on *titration* of metal ions in solution with chelating agents (see *chelation*), such as *EDTA* or other *complexons*.

complexon(e)s Complex-forming or chelating agents (see *chelation*) used in *complexometric analysis*; e.g. *EDTA* and similar compounds.

component (chem.) A term in the *phase rule*. The number of components in a system is the least number of substances from which every *phase* of the system may be constituted. E.g. each of the phases *ice*, *water*, *water vapour* in equilibrium is composed of one component, H_2O .

component forces and velocities Two or more *forces* or *velocities* that produce the same effect upon a body as a single force or velocity, known as the *resultant*.

compound (chem.) A substance consisting of two or more *elements* chemically united in definite proportions by *weight*.

compound, interstitial A *compound* of a *metal* and certain *metalloids* in which the *metalloid atoms* occupy the *interstices* between the *atoms* of the *metal lattice*.

compressibility The coefficient of compressibility (*isothermal*) of a substance is given by $\kappa = -1/V \cdot \delta V / \delta p$, where δV is the change in the *volume* V of the substance resulting from a change of *pressure* δp , the *temperature* remaining constant. The *reciprocal* of *bulk modulus*. Measured in *square metres per newton*.

Compton effect The reduction in the *energy* of a *photon*, as a result of its interaction with a free *electron*. Part of the photon's energy is transferred to the electron (Compton or recoil electron) and part is redirected as a photon of reduced energy (Compton scatter). Named after Arthur H. Compton (1892-1962).

computer An *electronic* device that can accept data, apply a series of logical processes to it, and supply the results of these processes of information. Computers are used to perform complex series of mathematical calculations at very great speed; this makes them of great use for a variety of purposes, such as routine office calculations, control of industrial processes, and the control of spacecraft flight paths. Their ability to perform these operations depends not only on their mathematical capabilities, but also on their ability to store information and retrieve specified *bits* of information in the appropriate circumstances. The two main types of computer are: the *analog computer* in which numbers are represented by magnitudes of such physical quantities as *voltages*, mechanical movements, etc., and the *digital computer* in which numbers are expressed directly as *digits*, usually in the *binary notation*. This latter type is more versatile. See also *C.P.U.*; *store*; *software*; *backing storage*; *peripherals*; etc.

concave Curving inwards; thus, a concave (or bi-concave) *lens* is thinner at the centre than at the edges. See Fig. 24 under *lens*.

concavo-convex A term used to describe a *lens* that curves inwards on one side and outwards on the other. See Fig. 24 under *lens*.

concentrated (chem.) As applied to *reagents*, containing the minimum of *water* or other *solvent*; the opposite of *dilute*.

concentration c . The quantity of a substance present in a given space, or defined quantity of another substance. Concentration of *aqueous solutions* is usually expressed in *moles per cubic metre*. See also *molarity*.

concentration cell A *primary cell* whose *E.M.F.* is due to a difference in *concentration* between different parts of the *electrolyte*.

concentric Having the same centre. E.g. two concentric tubes would appear, in cross-section, as two concentric *circles*.

conchoidal fracture A type of break or fracture characteristic of an *amorphous solid*; an irregular break with a curved face exhibiting concentric rings.

CONCRETE

concrete A building material composed of stone, sand, cement, and water. Reinforced concrete has steel rods or meshes imbedded in it to increase its *tensile strength*.

condensation (chem.) A chemical change in which two or more molecules react with the elimination of water or of some other simple substance. E.g. *acetic anhydride*, $(\text{CH}_3\text{CO})_2\text{O}$, may be regarded as a condensation product of *acetic acid*, CH_3COOH , a molecule of the anhydride being formed when two molecules of the acid combine with the elimination of one molecule of water. See also *polymerization*.

condensation of vapour The change of vapour into liquid, which takes place when the pressure of the vapour becomes equal to the maximum vapour pressure of the liquid at that temperature.

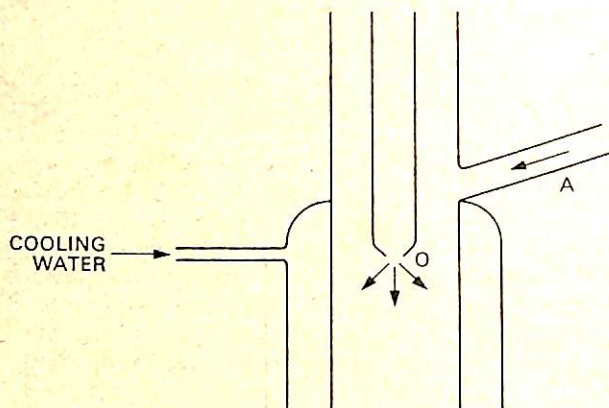


Figure 7.

condensation pump Diffusion pump. Apparatus used to obtain high vacua, i.e. pressures of the order of 10^{-6} mm mercury. Mercury or oil vapour issuing as a jet through the orifice O exhausts the system attached to the tube A. Gas molecules in A diffuse through the layer of mercury vapour around the orifice and are carried down with the vapour stream by molecular bombardment. The mercury vapour is cooled at the jet causing it to condense, so preventing it from diffusing back into the system that is being exhausted. See Fig. 7.

condenser (chem.) Liebig condenser. Apparatus for converting vapour into liquid during distillation. In its simplest form it consists of a tube along which the vapour passes and is cooled, usually by cold water flowing through an outer jacket surrounding the tube.

condenser, electrical See *capacitor*.

condenser, optical A device used in optical instruments to converge

rays of *light*; e.g. in the *microscope* a condenser *lens* is used to converge upon the object to be viewed.

condenser microphone A *microphone* consisting essentially of an electrical *condenser*, one plate of which is fixed and the other plate forms the diaphragm upon which the *sound waves* fall. The vibrations of the diaphragm vary the *capacitance* of the condenser, which in turn alters the *potential* across a high *resistance*. This varying potential is then amplified in the normal way.

conductance *G*. The conductance of a *direct current* circuit is the *reciprocal* of its *resistance*. The conductance of an *alternating current* circuit is its resistance divided by the square of its *impedance*. The *SI unit* is the *siemens*, formerly called the *mho* or reciprocal ohm.

conduction, thermal The transmission of *heat* from places of higher to places of lower *temperature* in a substance, by the interaction of *atoms* or *molecules* possessing greater *kinetic energy* with those possessing less. In *gases* the heat energy is transmitted by collision of the gaseous molecules, those possessing the greater kinetic energy imparting, on collision, some of their energy to molecules having less. Conduction in *liquids* is mainly due to the same process. In solid electrical *conductors*, the chief contribution to thermal conduction arises from a similar process taking place between the free *electrons* present. The interaction of the molecules responsible for thermal conduction in solid electrical *insulators* arises from the elastic binding *forces* between the molecules, which are effectively fixed in space.

conduction band The range of energies (see *energy bands*) in a *semiconductor* corresponding to states in which the *electrons* can be made to flow by an applied *electric field*.

conductivity, electrical σ . The *reciprocal* of the *resistivity* or specific resistance of a *conductor*. Measured in *siemens per metre*.

conductivity, thermal Heat conductivity. λ . The rate of transfer of *heat* along a body by *conduction*. Measured in *joules* flowing per second across a metre cube of the substance, having a *temperature* difference of 1 kelvin on opposite faces, in *SI units*.

conductometric titration A *titration* method in which the *end point* of a *neutralization* reaction is determined by changes in the electrical *conductivity* of the titrated solution during the addition of the titrant.

conductor, electrical A body capable of carrying an *electrical current*; a body that, if given an *electric charge*, will distribute that charge over itself.

conductor, thermal A body that will permit *heat* to flow through it by *conduction*.

Condy's fluid A *solution* of sodium or calcium (or sometimes

CONE

aluminium) permanganate, NaMnO_4 or $\text{Ca}(\text{MnO}_4)_2$. Used as a *disinfectant*.

cone (math.) A solid figure traced by a straight line passing through a fixed point, the *vertex*, and moving along a fixed *circle*. For a cone of vertical height h , slant height s , and radius of base r , the *volume* is given by $V = \pi r^2 h / 3$, and the area of the curved surface $A = \pi rs$.

confinement See *containment*.

conformation theory The principle that the three-dimensional structure of a *molecule* enables its stability and reactivity to be predicted. The theory pays special attention to the conformation of substituted hydrogen atoms in *organic* compounds; the axial (vertical) or equatorial (horizontal) disposition of *substituents* has been shown to be of great importance in predicting physical and chemical properties.

congruent figures Geometrical figures equal in all respects.

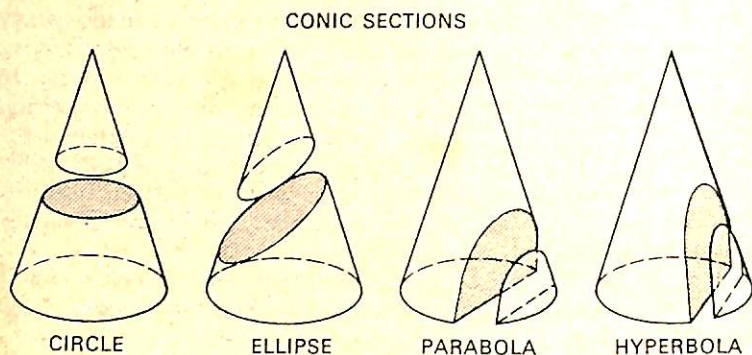


Figure 8.

conic sections Curves obtained by the intersection of a *plane* with a *cone*; they include the *circle*, *ellipse*, *parabola*, and *hyperbola*. See Fig. 8.

coniine $\text{C}_8\text{H}_{17}\text{N}$. A poisonous *liquid alkaloid*, b.p. $166-8^\circ\text{C}$., which is the active constituent of hemlock.

conjugated double bond In an *unsaturated organic compound* two *double bonds* separated by a single bond are said to be conjugated, e.g. *butadiene*, $\text{CH}_2:\text{CH}:\text{CH}:\text{CH}_2$.

conjugate points of a lens. Points on either side of the *lens*, such that an object placed at either will produce an image at the other.

conjunction (astr.) A *planet* (or other heavenly body) is said to be in superior conjunction when it is in a straight line with the *Sun* and the *Earth*; a planet with its orbit inside that of the *Earth* is in inferior conjunction when it is between the *Sun* and the *Earth* and in line with them.

conservation of charge The principle that the total *electric charge* associated with a system remains constant: that electric charge can be neither created nor destroyed.

conservation of mass and energy A principle, resulting from Einstein's special theory of *relativity*, that combines the separate laws of the conservation of *energy* and of *mass*. The law of the conservation of energy states that in any system energy cannot be created or destroyed, and the law of the conservation of mass (or *matter*) states that in any system matter cannot be created or destroyed. These laws are now seen to be approximations that can only be applied to systems not involving *nuclear reactions* or *velocities* approaching the velocity of *light*. The general principle of the conservation of mass and energy, which is of universal applicability and which is based upon the *mass-energy equation*, states that in any system the sum of the mass and energy remains constant.

conservation of momentum The principle that the total *momentum* of two colliding bodies before impact is equal to their total momentum after impact. When *velocities* comparable to the speed of *light* are being considered, the variation of *mass* with *velocity* (see *relativity, theory of*) must be taken into account, and the expression for the momentum becomes:

$$\text{Momentum} = mv = m_0 v / \sqrt{1 - v^2/c^2}$$

where m_0 = rest mass, v = velocity of the body, and c = velocity of light.

consolute temperature Critical solution temperature. The temperature at which two partially miscible liquids become completely miscible.

constant (math., phys.) Any quantity that does not vary; e.g. π ('pi'), the ratio of the circumference to the diameter of any circle.

constantan An alloy of copper containing 10%-55% nickel; as its electrical *resistance* does not vary with *temperature* it is used in electrical equipment.

constant boiling mixture See *azeotropic mixture*.

constant composition, law of See *chemical combination, laws of*.

contact angle, for solid-liquid interface. The *angle* included between the tangent plane to the surface of a *liquid* and the tangent plane to the surface of a *solid* at any point along their line of contact.

contact potential difference If two dissimilar *metals*, a and b , are in contact (see Fig. 9 overleaf), then a *potential difference* exists between point A , just outside conductor a , and a point B , just outside conductor b . This is the contact potential difference of the two conductors.

contact process Industrial process for the manufacture of *sulphuric acid*, H_2SO_4 . *Sulphur dioxide*, SO_2 , is made to combine with oxygen by passing over a heated *catalyst*, usually platinum or

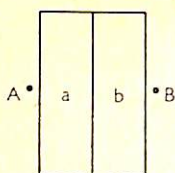


Figure 9.

platinized asbestos. The *sulphur trioxide*, SO_3 , formed is combined with *water* to give *sulphuric acid*.

containment Confinement. In a controlled *thermonuclear reaction*, the process of preventing the *plasma* from coming into contact with the walls of the containing vessel is referred to as *containment* or *confinement*. The approximate period for which the *ions* remain trapped by the containing field is referred to as the 'containment time' or the 'confinement time'.

continuous spectrum See *spectrum*.

continuous wave CW. *Radio* or *radar* transmissions generated continuously and not in short *pulses*.

continuum A continuous series of component parts passing into one another; e.g. the three *space* dimensions and the time dimension are considered to form a four-dimensional continuum.

control grid An *electrode* placed between the *cathode* and the *anode* of a *thermionic valve* for controlling the flow of *electrons* through the valve.

controlled thermonuclear reaction CTR. See *thermonuclear reaction*.

control rod Part of the control system of a *nuclear reactor* that directly affects the rate of reaction therein. Usually a rod or tube, which can be moved up or down its *axis*, made of steel or aluminium containing boron, cadmium, or some other strong absorber of *neutrons*.

convection Transference of *heat* through a *liquid* or *gas* by the actual movement of the *fluid*. Portions in contact with the source of heat become hotter, expand, become less dense, and rise; their place is taken by colder portions, thus setting up convection currents.

conventional current An electric *current* that is, by convention, regarded as flowing from a point of high potential to one of low potential. In fact, a current consisting of a flow of *electrons* flows in the opposite direction.

convergence 1. The process of coming to a point. See *converging lens*.

2. The process of tending to approach a finite limiting value. A

converging series is one in which the sum of the terms tends towards a finite figure.

converging lens A *lens* capable of bringing to a point a *beam of light* passing through it; a *convex lens*. See Fig. 25 under *lens*.

converse The transposition of a statement consisting of a fact or datum and a consequent conclusion. Thus the converse of the proposition 'equal chords of a *circle* are equidistant from the centre' is 'chords that are equidistant from the centre of a circle are equal'. The converse of a statement is not necessarily true.

conversion The process in a *nuclear reactor* as a result of which *fertile* material is transformed into *fissile* material, e.g. the conversion of thorium-232 into uranium-233. The 'conversion factor' is the number of fissile *atoms* produced from the fertile material per fissile atom destroyed in the fuel.

conversion electron An *orbital electron* ejected from an *atom* as a result of the *energy* it acquires from a transition of the *nucleus* from one energy state to another in the absence of *gamma-ray* emission. See also *internal conversion*.

converter 1. An electrical machine for converting *alternating current* to *direct current* or vice versa. 2. The *retort* used in the *Bessemer process*.

converter reactor A *nuclear reactor* that produces *fissile* material from *fertile* material by *conversion*.

convex Curving outwards; e.g. a *convex lens*, one thicker at the centre than at the edges. See Fig. 24 under *lens*.

coolant A *fluid* used for cooling, usually extracting *heat* from one source and transferring it to another. In a *nuclear reactor* the coolant transfers the heat from the *nuclear reaction* to the steam-raising plant.

coordinate bond Dative Bond. Semipolar bond. See *valence*, *electronic theory of*.

coordinate geometry See *analytical geometry*.

coordinates Magnitudes used to define the position of a point or line within a fixed frame of reference. See *Cartesian coordinates* and *polar coordinates*.

coordination compound A compound in which the *molecule* or a component *ion* of the molecule contains a central atom surrounded by atoms or groups of atoms (called *ligands*) attached to the central atom by a number of *valence bonds* in excess of the *stoichiometric valence* of the central atom. Thus, a *ferricyanide* is a coordination compound: in its *anion* the central iron atom, which has a valence of three, is attached to six CN groups.

coordination number 1. In a *crystal lattice*, the number of *anions* that surround a *cation*. 2. In the molecule of a *coordination compound*, the number of atoms directly linked to the central atom.

COPAL

copal A natural *resin* obtained from certain trees. Used in varnishes.

coplanar (math.) In the same *plane*.

copolymerization See *polymerization*.

copper Cu. Element. A.W. 63.54. At. No. 29. A red malleable and ductile *metal*, m.p. 1084°C., r.d. 8.95; after silver, the best *conductor* of electricity. It is unaffected by *water* or *steam*. It occurs as the free metal, and as *cuprite* or *ruby ore*, Cu_2O ; *chalcocite*, Cu_2S ; *chalcopyrite*, CuFeS_2 . Extracted from *sulphide* ores by alternate roasting and fusing with sand, thus removing iron and *volatile* impurities, and leaving a mixture of *cuprous oxide* and *sulphide*. This is then heated in a *reverberatory furnace*, giving impure copper, which is then refined by various methods. Used for steam boilers, electrical wire and apparatus, in *electrotyping*, and in numerous *alloys*, e.g. *bronze*, *brass*, *speculum metal*, *gun metal*, *bell metal*, *Dutch metal*, *manganin*, *constantan*, *nickel silver*, *German silver*, etc.

copperas See *ferrous sulphate*.

copper glance See *chalcocite*.

copper pyrites See *chalcopyrite*.

copper sulphate See *cupric sulphate*.

coral Deposits of impure *calcium carbonate*, CaCO_3 , formed of the hard skeletons of various marine *organisms*.

cordite An *explosive* prepared from *cellulose nitrate* and *nitroglycerine*.

core 1. Magnetic material that is used to increase the inductance of a coil through which it passes. It may be laminated or made of compressed ferromagnetic particles. 2. The central part of a *nuclear reactor* that contains the fissile material. 3. The devices, *semiconductors*, *ferrite* rings, etc., that constitute the memory of a computer.

Coriolis force A fictitious force used to simplify calculations involving rotating systems, such the movement of air on the surface of the Earth. For example, to an observer on a rotating disc, a particle moving in a straight line from the centre of the disc to its circumference would appear to be moving in a curved path. The Coriolis force is the fictitious force required to account for the tangential acceleration. Named after Gaspard de Coriolis (1792-1843).

corona A white irregular halo surrounding the *Sun*, which is visible during a total *eclipse*.

corona discharge A luminous discharge that appears round the surface of a *conductor* due to *ionization* of the air (or other gas surrounding it), caused by the *voltage* gradient exceeding a critical value, but not being sufficient to cause sparking.

corpuscle See *blood cell*.

corpuscular theory The theory that *light* consists of minute corpuscles in rapid motion. The original corpuscular theory was abandoned in

the middle of the nineteenth century in favour of the *wave theory of light*, first put forward by Huygens in 1678. Later research has shown that light phenomena must be interpreted in terms of *photons* and waves, as the two descriptions are merely two different ways of viewing one and the same reality. See *complementarity*.

corrosion Surface chemical action, especially on *metals*, by the action of moisture, air, or chemicals.

corrosive sublimate See *mercuric chloride*.

cortisone 17-hydroxy-11-dehydrocorticosterone. $C_{21}H_{28}O_5$. A crystalline *steroid hormone*, m.p. 215°C ., secreted by the cortex of the adrenal gland. It produces healing responses and reduces local inflammation, used in the treatment of rheumatic conditions.

corubin Crystalline *aluminium oxide*, Al_2O_3 . Obtained as a *by-product* of the *aluminothermic reduction*.

corundum Natural *aluminium oxide*, Al_2O_3 . A crystalline substance nearly as hard as *diamond*, used as an *abrasive*.

cosecant See *trigonometrical ratios*.

cosine See *trigonometrical ratios*.

cosmic dust Small particles of *matter*, probably ranging in size from one hundredth to one ten-thousandth of a *millimetre*, distributed throughout *space*.

cosmic rays Very energetic *radiation* falling upon the Earth from outer *space*, and consisting chiefly, if not entirely, of charged particles. The majority of these are most probably *protons*, although *electrons* and *alpha particles* are also present. There is also evidence that a small component (about 2%) of the primary radiation consists of heavy atomic *nuclei*. The primary particles, when incident upon our atmosphere, cause several secondary processes. Proton-neutron collisions in the top tenth of the atmosphere give rise to *mesons*. High-energy electrons are created in the atmosphere by meson decay, by interaction of high energy protons with nuclei, by *knock-on* collisions of mesons with electrons, etc. These high-energy electrons give rise to *cosmic ray showers* resulting in the creation of *photons*, *positrons*, and further electrons. Energies as high as 10^{17} *electron-volts* have been observed with cosmic ray particles. The origin of cosmic rays is not known with certainty although some appear to emanate from the *Sun*. See also *east-west asymmetry*.

cosmic ray shower Cascade shower. See *shower*.

cosmogony The science of the nature of the heavenly bodies, with particular reference to the formation of *planets*, *stars*, and *galaxies*.

cosmology The science of the nature, origin, and history of the *Universe*. A more general and widely used term than *cosmogony* when referring to the Universe as a whole. See *steady state theory*; *superdense theory*.

cosmotron A *proton accelerator* containing a very large ring-shaped *electromagnet*.

COTANGENT

cotangent See *trigonometrical ratios*.

Cottrell precipitator A device used for removal of dust particles from gases by *electrostatic precipitation*.

COUDÉ TELESCOPE

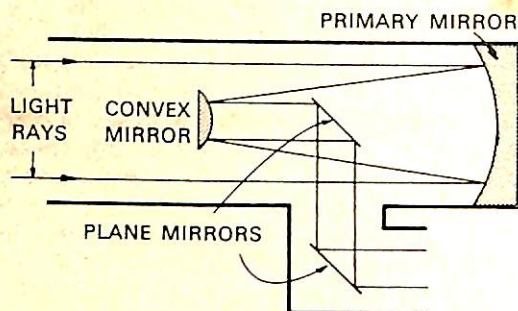


Figure 10.

Coudé system A form of astronomical reflecting *telescope* in which *light* from the *primary mirror* is reflected back along the axis of the telescope by means of a system of mirrors as shown in Fig. 10. This system may also be adapted for use with a refracting telescope.

coulomb The derived *SI unit of electric charge*, defined as the quantity of electricity transferred by 1 *ampere* in one second. 10^{-1} *electromagnetic unit*; 3×10^9 *electrostatic units*. Symbol C. Named after Charles Augustin Coulomb (1736-1806).

Coulomb scattering The *scattering* of sub-atomic particles caused by the *electrostatic* (coulomb) *field* surrounding an atomic *nucleus*.

Coulomb's law The *force* of attraction or repulsion between two charged bodies (whose charges behave as though they were concentrated at a point) is proportional to the magnitude of the charges and inversely proportional to the square of the distance between them. In *SI units*, the equation is written $F = q_1 q_2 / 4\pi\epsilon_0 d^2$, where F is the force in newtons, q_1 and q_2 are the charges in coulombs, d is the distance between them in metres, and ϵ_0 is the *electric constant*.

coulometer Coulombmeter. See *voltmeter*.

coumarin $C_9H_6O_2$. A white crystalline substance, m.p. 71°C ., with an odour of vanilla. Used as a flavour and in perfume.

coumarone Benzofuran. $C_6H_4OCH:CH$. A *liquid* derived from *coal-tar*, b.p. 173°C ., that polymerizes into a synthetic *resin*; used in the *paint* and *varnish* industry.

counter tube A device for counting individual ionizing events. See *Geiger counter*; *scintillation counter*; *crystal counter*.

couple (phys.) Two equal and opposite parallel, but not colinear, *forces* acting upon a body. The *moment* of a couple is the product of either force and the perpendicular distance between the line of action of the forces.

coupling reaction See *azo coupling*.

covalent bond See *valence, electronic theory of*.

covalent crystal A *crystal* in which the *atoms* are held in the *lattice* by covalent bonds (see *valence, electronic theory of*). Typical examples are *diamond*, *silicon*, and most organic crystals. See also *semiconductors*.

C.P.U. Central processing unit. The central *electronic* unit in a *computer* that processes input information, and information from the *store*, and produces the output information. The C.P.U. and the store form the central part of the computer. The devices connected to them, known as *peripherals*, include the *backing storage* and the input and output equipment.

cracking (chem.) Pyrolysis. The *decomposition* of a chemical substance by *heat*; especially the conversion of *mineral oils* of high *boiling point* into more *volatile* oils suitable for petrol engines, by 'cracking' the larger *molecules* of the heavy oils into smaller ones. In catalytic cracking the decomposition takes place in the presence of a *catalyst*.

cream of tartar See *potassium hydrogen tartrate*. $C_4O_6H_5K$.

creatinine $C_4H_7N_3O$. A white crystalline substance, derived from the *amino acid* creatine, $C_3H_8N_3COOH$, found in urine, blood, etc.

creep A permanent change in the physical dimensions of a *metal* caused by the application of a continuous *stress*.

creosote A *distillation* product obtained from *coal-tar* or from the tar obtained by the *destructive distillation* of wood. An oily, transparent *liquid* containing *phenol* and *cresol*, it is used for preserving timber.

cresol Hydroxytoluene. $CH_3C_6H_4OH$. A *liquid aromatic organic compound* obtained from *coal-tar*. It consists of three *isomers*, which boil in the range 191° - $203^\circ C$. Used in the *plastics*, *explosives*, and *dye* industries, and as a *disinfectant*. See *Lysol*.

crith The *weight* of 1 litre of hydrogen at $0^\circ C$, and a pressure of 760 mm; approximately 0.09 g.

critical angle of a medium (phys.) The least angle of *incidence* at which *total internal reflection* occurs. When a ray of *light* passing from a denser to a less dense medium, e.g. *glass* to *air*, meets the surface, a portion of the light does not emerge, but is internally reflected. As the angle of incidence increases, the intensity of the internally reflected beam also increases until an angle is reached when the whole beam is thrown back, total internal reflection taking place.

critical damping A measuring instrument is said to be critically damped when it takes up its *equilibrium* deflection in the shortest possible

CRITICAL MASS

time, the oscillations of the indicator (needle) about the equilibrium position being quickly damped out. *Galvanometers* are normally used critically damped.

critical mass The minimum amount of *fissile* material required in a *nuclear reactor* or a *nuclear weapon* to sustain a *chain reaction*.

critical potential The minimum *energy* required to raise the *energy level* of an *orbital electron* (see *excitation*) or to remove it from the atom. See *ionization potential* and *radiation potential*.

critical pressure The pressure of the *saturated vapour* of a substance at the *critical temperature*.

critical reaction See *chain reaction*.

critical state Critical point. The state of a substance when its liquid and gaseous phases have the same *density*, at the same *temperature* and *pressure*.

critical temperature The *temperature* above which a gas cannot be liquefied by *pressure* alone.

critical velocity The *velocity* at which the flow of a *liquid* ceases to be *streamline* and becomes *turbulent*.

critical volume The *volume* occupied by unit mass of a substance at its *critical temperature* and *critical pressure*.

cross-linkage (chem.) The joining of polymer molecules (see *polymerization*) to each other by *valence bonds*. A polymer may be imagined, in the simplest case, to consist of very long chain-like molecules; cross-linkage would have the effect of joining adjacent chains by lateral links.

cross-section In *nuclear physics* the cross-section represents the effective area that has to be attributed to a particular *atom* or *nucleus* to account geometrically for its interaction with an incident *beam* of *radiation*. The 'total' (or 'collision') cross-section, which accounts for all interactions, is subdivided into the 'elastic cross-section' and the 'inelastic cross-section'. The elastic cross-section accounts for all elastic *scattering* in which the incident radiation suffers no loss of *energy* to the atom or nuclei. The inelastic cross-section accounts for all other interactions and may be further subdivided to account for specific interactions, e.g. 'capture cross-section', 'fission cross-section', 'ionization cross-section', etc.

crotonic acid Butenoic acid. $\text{CH}_3\text{CH}:\text{CHCOOH}$. A colourless crystalline *soluble* substance that exists in two *isomeric* forms. The *trans*-form has a m.p. 71.6°C . and is used in organic synthesis. The *cis*-form (isocrotonic acid) has a m.p. of 14.5°C .

crown glass A variety of *glass* containing potassium or barium in place of sodium; it is less fusible than ordinary *soda glass*, and is used in optical instruments.

crucible A vessel of heat-resisting material used for containing high temperature *chemical reactions*.

cryogen See *freezing mixture*.

cryogenics The study of materials and phenomena at *temperatures* close to *absolute zero*.

cryohydrates Crystalline substances, containing the *solute* with a definite molecular proportion of *water*, that crystallize out from *solutions* cooled below the *freezing point* of pure *water*.

cryolite Natural sodium aluminium fluoride, Na_3AlF_6 . Used in the manufacture of *aluminium*.

cryometer A *thermometer* especially designed for measuring low *temperatures*.

cryophorus An apparatus used to demonstrate the cooling effect of *evaporation*.

cryoscopic method for the determination of *molecular weights*; freezing-point method. The determination of the molecular weight of a dissolved substance by noting the *depression of freezing point* produced by a known *concentration*.

cryostat A vessel in which a specified low *temperature* may be maintained.

cryotron A switch based on *superconductivity*. The simplest form consists of a coil of wire of one superconducting material wound round a length of wire of another superconductor, all immersed in a bath of liquid helium. A control current passed through the coil produces a *magnetic field* strong enough to destroy the *superconductivity* of the central wire but not of the coil. Thus the current in the coil controls the *resistance* of the wire, switching it from zero to a finite value.

crystal A substance that has solidified in a definite geometrical form. Most *solid* substances, when pure, are obtainable in a definite crystalline form. Solids that do not form crystals are said to be *amorphous*. Crystals are classified according to the structure of their *lattices*, or according to the type of *bond* that holds them together, i.e. *electrovalent* (or *ionic crystals*), *covalent crystals*, or *metallic crystals*.

crystal counter A *counter tube* that depends upon a *crystal* in which the electrical *conductivity* is momentarily increased by an ionizing event.

crystal detector See *detector*. A fine wire ('cat's whisker') in contact with a crystal of *galena* (PbS) or other suitable *semiconductor*. This arrangement is a good conductor of *electricity* in one direction, and suppresses most of the flow of electricity in the other direction.

crystallography The study of the geometrical form of *crystals*. See *X-ray crystallography*.

crystalloids Substances that, in *solution*, are able to pass through a *semipermeable membrane*; substances that do not usually form *colloidal solutions*.

CRYSTAL MICROPHONE

crystal microphone A microphone in which the sound waves to be amplified or transmitted vibrate a *piezoelectric crystal*, which generates a varying E.M.F.

crystal oscillator A source of electrical oscillations of very constant frequency determined by the physical characteristics of a *quartz crystal*. See *quartz clock*.

crystal pick-up A pick-up in a record player in which the varying E.M.F. is produced by a *piezoelectric crystal* as a result of the vibrations obtained from the undulations in the groove of the record.

crystal rectifier A *semiconductor* used as a *rectifier*, usually in a manner similar to a *diode valve*; also called a semiconductor diode.

crystal systems The seven classes into which crystals are divided: cubic, tetragonal, orthorhombic, hexagonal, trigonal, monoclinic, and triclinic. The definition of each class depends on the relative lengths of the sides of the *unit cell* and the angles between them.

CS (*o*-chlorobenzylidene)-malononitrile. $C_6H_4ClCH:C(CN)_2$. A white powder, m.p. $52^\circ C$., used as a tear gas and 'harassing agent' in crowd control. It causes tears, salivation, choking, and painful breathing.

cube 1. A regular hexahedron; a regular solid figure with six square faces. 2. The third power of a number. E.g. 8 is the cube of 2^3 .

cube root $\sqrt[3]{}$. The cube root of a number is the quantity that when raised to the third power gives that number. Thus 2 is the cube root of 8.

cubic centimetre cc. Metric unit of volume. $1000\text{ cc} = 1\text{ litre}$. It is sometimes used synonymously with *millilitre*, ml., one thousandth of a litre, although the litre is no longer used for accurate measurements.

culture medium A preparation used for growing and cultivating *microorganisms* for experimental purposes.

cumene Isopropylbenzene. $C_6H_5CH(CH_3)_2$. A colourless liquid aromatic hydrocarbon, b.p. $152^\circ C$. It occurs in *petroleum* and is used as an *intermediate* in *organic synthesis*.

cupel A dish used in the extraction of the *noble metals* by *cupellation*.

cupellation The separation of silver, gold, and other *noble metals* from impurities that are oxidized by hot air. The impure metal is placed in a *cupel*, a flat dish made of porous *refractory* material, and a blast of hot air is directed upon it in a special furnace. The impurities are oxidized by the air and are partly swept away by the blast and partly absorbed by the cupel.

cuprammonium A loose term for *complex compounds* formed by copper with *ammonia ligands*; in particular, compounds containing the bivalent tetraamminecopper(II) cation, $[Cu(NH_3)_4]^{2+}$. Cuprammonium solution was used in the manufacture of *rayon* by the now obsolete cuprammonium process. See *Schweitzer's reagent*.

- cupric** Containing *bivalent* copper. Most of the commoner copper compounds are cupric salts.
- cupric oxide** CuO . A black insoluble substance that decomposes at 1026°C . on heating. It has various industrial uses.
- cupric sulphate** Copper sulphate, blue vitriol. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. A blue crystalline *soluble* salt. Used as a *mordant*, an *insecticide*, and a *fungicide*.
- cupro-nickel** An *alloy* of copper and nickel used in coinage.
- cuprous** Containing *univalent* copper.
- cuprous oxide** Red copper oxide. Cu_2O . It occurs in nature as the mineral cuprite. It is a red *insoluble* powder, m.p. 1235°C ; formed when *Fehling's solution* is reduced. Used in *glass* manufacture and in *paints* and *fungicides*.
- curare** A very poisonous material, containing certain *alkaloids*. Obtained from various South American trees.
- curie** A measure of the *activity* of a *radioactive* substance (see *radioactivity*). Originally defined as the quantity of *radon* in radioactive equilibrium with 1 g of radium. Now extended to cover all radioactive *isotopes* and defined as that quantity of a radioactive isotope which decays at the rate of 3.7×10^{10} *disintegrations* per second. Named after Madame Marie Curie (1867-1934).
- Curie point** Curie temperature. The temperature for a given *ferromagnetic* substance above which it becomes merely *paramagnetic*. Named after Pierre Curie (1859-1906).
- Curie's law** The *magnetic susceptibility* of a *paramagnetic* substance is inversely proportional to the *absolute temperature*. Named after Pierre Curie.
- curium** Cm. *Transuranic element*, At. No. 96. A radioactive *actinide* whose most stable *isotope*, $^{247}_{96}\text{Cm}$, has a *half-life* of 1.6×10^7 years.
- current**, electric. See *electric current*.
- current balance** An instrument for the determination of an *electric current* by measuring the *force* that the current produces between conductors. A common type consists of two similar coils attached to the extremities of a balance arm. Above and below each of these coils is a fixed coil. The six coils are connected in series in such a way that when the current is allowed to pass through them, the beam experiences maximum *torque*. The beam is restored to its horizontal *equilibrium* position by means of a known torque supplied by a rider sliding along the arm. From the known torque and the geometry of the system the current can be calculated.
- current density** 1. The current flowing through a conductor, *plasma*, etc., per unit cross-sectional area. It is usually expressed in amperes per square metre. 2. (in *electrolysis*) The current flowing per unit area of electrode.

CURSOR

cursor A transparent slider with a fine hair-line, used in *slide-rules*.

cyanamide NH_2CN . A colourless crystalline *unstable* substance, m.p. 44°C . Name often applied to *calcium cyanamide*.

cyanate A salt or ester of *cyanic acid*.

cyanide A salt of *hydrocyanic acid*, HCN . All cyanides are intensely poisonous.

cyanide process for gold. Extraction of gold from its *ores* by dissolving the gold in a *solution* of potassium cyanide, KCN , reducing the resulting potassium aurocyanide, $\text{KAu}(\text{CN})_2$, with zinc, filtering off, melting down, and cupelling (see *cupellation*) the metal.

cyanine dyes The molecule of a cyanine dye contains a chain of carbon atoms with *conjugated double bonds* forming a bridge between two *heterocyclic nuclei*. They are used for photographic *sensitization*.

cyanite Al_2SiO_5 . A blue mineral consisting of aluminium silicate, used as a *refractory*.

cyanocobalamin Vitamin B_{12} . $\text{C}_{63}\text{H}_{90}\text{O}_{14}\text{N}_{14}\text{PCo}$. A red crystalline *soluble* substance, obtained from liver, eggs, fish, etc., used in the treatment of pernicious anaemia, and to promote the growth of livestock.

cyanogen C_2N_2 . A colourless, very poisonous gas with a smell of bitter almonds. In its chemical properties it resembles the *halogens*, forming *cyanides* analogous to the *chlorides*, etc.

cyano group The *univalent radical*— CN .

cyanoguanidine See *dicyandiamide*.

cyanuric acid Tricyanic acid. $\text{C}_3\text{H}_3\text{O}_3\text{N}_3 \cdot 2\text{H}_2\text{O}$. A white crystalline *soluble* substance, used in organic synthesis.

cybernetics The theory of communication and control mechanisms in living beings and machines.

cybotaxis The tendency of *molecules* in *liquids* to form regularly arranged groups, resembling *crystals*. See *liquid crystals*.

cyclamate See *sodium cyclamate*; *calcium cyclamate*.

cycle (phys.) Any series of changes or operations performed by or on a system, which brings it back to its original state. E.g. the *frequency* of an *alternating current* is measured in cycles per second. (See also *hertz*.)

cyclic (chem.) Having a ring structure. See *carbocyclic* and *heterocyclic compounds*.

cyclic figure (math.) A figure through all the vertices or corners of which a *circle* may be drawn; a figure inscribed in a circle.

cyclic quadrilateral A four-sided plane *rectilinear* figure through the vertices of which a *circle* may be drawn. The pairs of opposite angles are *supplementary* (i.e. total 180°).

cyclization The conversion of an open chain molecule into a *cyclic* compound.

cyclohexane C_6H_{12} . A colourless inflammable *liquid*, b.p. 81°C .,

- consisting of a six-membered ring of *methylene groups*. Used as a *solvent* and in the manufacture of *plastics*.
- cyclohexanol** $C_6H_{11}OH$. A crystalline *soluble* substance, m.p. $25.1^\circ C$., b.p. $161.1^\circ C$., used as a *solvent*.
- cycloid** A figure traced out in space by a point on the circumference of a *circle*, which rolls without slipping along a fixed straight line.
- cycloñite** Hexogen, RDX*. $(CH_2N.NO_2)_3$. A very powerful *explosive* made from *hexamine*.
- cyclopentane** C_5H_{10} . A colourless *liquid*, b.p. $49.2^\circ C$., obtained from *petroleum* and used as a *solvent*.
- cyclopropane** C_3H_6 . A colourless inflammable gas, used as an *anaesthetic*.
- cyclotron** An *accelerator* for imparting to charged particles of atomic magnitudes *energies* of several million *electron-volts*. The *ions* or charged particles are caused to traverse a spiral path between two hollow semicircular *electrodes*, called *dees*, by means of a suitable *magnetic field* applied perpendicularly to the plane of the *dees*. At each half-revolution the particles receive and energy increase of some tens of thousands of electron-volts from an oscillating *voltage* applied between the *dees*.
- cylinder** A solid figure traced out by a rectangle rotating round one side as *axis*. For a cylinder having vertical height h and radius of base r , the volume is $\pi r^2 h$ and the total surface area $2\pi r(h + r)$.
- cysteine** A crystalline *amino acid*, present in most *proteins*. See Appendix, Table 5.
- cystine** An *insoluble* crystalline *amino acid*, m.p. $247-9^\circ C$., which forms *cysteine* on *reduction*. See Appendix, Table 5.
- cytochemistry** The *chemistry* of living *cells*.
- cytochrome** A respiratory *pigment* widely distributed in *aerobic organisms*. It consists of *proteins* with an iron *prosthetic group* similar to that of *haemoglobin*. The *oxidation* of cytochrome by molecular oxygen, and its subsequent *reduction* in the cell, is the principal route by which atmospheric oxygen enters into cellular *metabolism*.
- cytokinins** *Plant hormones* that promote *cell* division in plants. They have potential uses in prolonging the freshness of vegetables and cut flowers.
- cytology** The study of the structure and function of living *cells*.
- cytolysis** The dissolution of *cells*, particularly by the destruction of their surface membranes.
- cytoplasm** The *protoplasm* of a living *cell* outside its *nucleus*.
- cytosine** Aminopyrimidone. $C_4H_5N_3O$. A white crystalline substance, m.p. $320-25^\circ C$. One of the *pyrimidine* bases that occur in the *nucleotides* of the *nucleic acids* and play a part in the formulation of the *genetic code*.

D

daily variation of the Earth's magnetic field (see *magnetism, terrestrial*).

The small variation of the *horizontal intensity*, *magnetic declination*, and *dip* recurring over a period of a day.

dalton An alternative name for the *atomic mass unit*.

Dalton's atomic theory See *atomic theory*.

Dalton's law of partial pressures. The total *pressure* of a mixture of two or more *gases* or *vapours* is equal to the sum of the pressures that each component would exert if it were present alone, and occupied the same *volume* as the whole mixture. Named after John Dalton (1766-1844).

damping A decrease in the *amplitude* of an oscillation or *wave motion* with time. See also *critical damping*.

Daniell cell A *primary cell* having a negative pole of amalgamated zinc, standing in a porous pot containing dilute *sulphuric acid*. This pot stands in *cupric sulphate solution*, which also contains the positive pole, a copper plate. On completion of the external circuit, a current flows and the following reactions take place: at the negative pole, zinc is dissolved, *zinc sulphate* being formed; at the positive pole, copper is deposited. The *E.M.F.* is 1.1 volts. Named after J. F. Daniell (1790-1845).

daraf The practical unit of *elastance*; *reciprocal* of the *farad*.

dark ground illumination A device used in microscopy, whereby transparent or unstained objects are made to appear as bright particles on a black background.

Darwin's theory of evolution. The theory that different species arise by the process of *natural selection*. Named after Charles Darwin (1809-82).

dash-pot A mechanical damping device that depends upon the fact that when a body moves through a *fluid* medium, *viscous forces* are set up, which damp the motion of the body. It usually consists of a piston, attached to the part whose movements are to be damped, fitting loosely into a cylinder containing either air or oil.

dasymeter An instrument for determining the *density* of a *gas*.

dating The determination of the age of *mineral*, *fossil*, or wooden objects by measuring their *radioactivity*. See also *radiocarbon dating*; *potassium-argon dating*; *rubidium-strontium dating*; *radioactive age*.

dative bond Coordinate bond. A *covalent type* of *bond* in which both *electrons* forming the bond are donated by one *atom*. See *valence*, *electronic theory of*.

Davy lamp See *safety lamp*.

DDT Dichlorodiphenyltrichloroethane. $(C_6H_4Cl)_2.CH.CCl_3$. A white powder, m.p. $107^\circ C$., with a fruity smell. Used as a contact insecticide.

deaminase An *enzyme* that catalyses the removal of an *amino group* from a *compound*.

deamination The removal of *amino groups* from a *compound*.

Dean and Stark method A method of estimating the quantity of water in an oil or other *liquid* substance. The liquid under examination is distilled into a special *reflux condenser* so constructed that the water is prevented from running back into the distillation flask. The volume of water so collected is measured and thus the water content of a known weight of initial liquid can be calculated.

de Broglie wavelength A moving particle, whatever its nature, has wave properties associated with it. For a particle of mass m moving with velocity v , the wavelength of the associated de Broglie wave is given by $\lambda = h/mv$, where h is *Planck's constant*. Named after Louis Victor de Broglie (born 1892).

debye A unit of molecular *dipole* moment equal to 1×10^{-18} electrostatic unit or $3.335\ 64 \times 10^{-30}$ coulomb metre. Named after Peter J. W. Debye (1884-1966).

Debye and Huckel's theory of electrolytic dissociation. See *electrolytic dissociation, theory of*.

deca- Prefix denoting ten times in the *metric system*. Symbol da, e.g. dam = 10 metres.

decane $C_{10}H_{22}$. A liquid paraffin hydrocarbon, b.p. $174.1^\circ C$., that occurs in several isomeric forms.

decanoic acid Capric acid. $C_9H_{19}COOH$. A white crystalline organic acid with an unpleasant odour, m.p. $31.5^\circ C$. Decanoate esters are used in the manufacture of flavouring substances and perfumes.

decantation The separation of a solid from a liquid by allowing the former to settle and pouring off the latter.

decay The transformation of a radioactive substance into its decay (or daughter) products. (See *radioactivity*). Also used in relation to the transformation of particles into more stable particles.

decay, period of See *half-life*.

decay constant See *disintegration constant*.

deci- Prefix denoting one tenth in the *metric system*. Symbol d, e.g. dm = 0.1 metre.

decibel One tenth of a *bel*. A unit for comparing levels of power. Two power levels, P_1 and P_2 , are said to differ by n decibels when:

$$n = 10 \log_{10} P_2/P_1$$

This unit is often used to express sound intensities. In this case, P_2 is the intensity of the sound under consideration and P_1 is the

DECLINATION

intensity of some reference level, often the intensity of the lowest audible note of the same *frequency*.

declination (astr.) The *angular distance* of a heavenly body from the *celestial equator*.

declination, magnetic See *magnetic declination*.

decomposition (chem.) The breaking up of chemical compounds under various influences; e.g. by chemical action, by heat (*pyrolysis*), by an electric current (*electrolysis*), by biological agents (*biodegradation*), etc. See also *degradation*.

decrepitation Bursting or cracking of *crystals* of certain substances on heating, mainly due to expansion of water within the crystals.

defect A discontinuity in the pattern of *atoms*, *ions*, or *electrons* in a *crystal*. A 'point defect' consists of a *vacancy* or an *interstitial*. A 'line defect' is caused by a *dislocation*. In a *semiconductor*, 'defect conduction' is a result of *hole* conduction in the *valence band*.

deferent See *epicycle*.

deficiency diseases Diseases produced by lack of a particular *vitamin* or other essential food factor in the diet; e.g. scurvy, caused by the deficiency of vitamin C.

definition The sharpness of an *image* formed by a *lens*, *mirror*, or other optical system: the accuracy of *sound* or vision reproduction in a *radio* or *television set*.

deformation An alteration in the size or shape of a body.

deformation potential The *electric potential* that acts on a *free electron* in a *conductor* or *semiconductor* as a result of *deformation* of the *crystal lattice*.

degaussing The *demagnetization* of a magnetized substance, achieved by surrounding the substance with a coil carrying an *alternating current* of ever-decreasing magnitude.

degenerate gas A state of *matter* in which *electrons* and atomic *nuclei* are packed too closely together for the evolution of *nuclear energy*; occurs in *stars* of the *white dwarf* class.

degradation (chem.) In general, the breakdown of *molecules* into simpler fragments; the stepwise decrease of the length of *polymer macromolecules*. See also *depolymerization*.

degree 1. A subdivision of an interval in a scale of measurement ; e.g. the *Celsius degree*. 2. A measure of *angle*. One three hundred and sixtieth of the angle traced by the complete revolution of a line OA about the point O, until it returns to its original position. 3. The sum of the *exponents* of the *variables* in a mathematical expression: the exponent of the *derivative* of highest order in a *differential equation*.

degree of latitude and longitude See *latitude*; *longitude*.

degrees of freedom (chem.) 1. A term used in the *phase rule*; the least number of independent variables defining the state of a system (e.g. the *temperature* and *pressure* in the case of a *gas*) that must be

- given definite values before this state is completely determined. 2. The number of independent ways in which a *molecule* may possess translational, vibrational, or rotational *energies*.
- dehydration** The elimination or removal of *water*; usually the removal of chemically combined water. E.g. concentrated *sulphuric acid*, H_2SO_4 , acts as a dehydrating agent on substances that contain hydrogen and oxygen in the proportions in which they occur in water.
- dehydrogenase** An *enzyme* that catalyses *oxidation* reactions by the removal of hydrogen from the *substrate*.
- dekatron** A gas-filled emission tube with a central *anode* usually surrounded by ten *cathodes* and associated transfer *electrodes*. Incoming pulses cause a *glow discharge* to be transferred from one cathode to the next so that the tube may be used for counting or switching.
- delayed neutrons** *Neutrons* resulting from *nuclear fission* that are emitted with a measurable time delay. Only a small proportion of neutrons are delayed, but the average delay period must be taken into account in the control of *nuclear reactors*. See *prompt neutrons*.
- delay line** A component or circuit designed to introduce a calculated delay in the transmission of a signal.
- deliquescent** Having the property of picking up moisture from the air to such an extent as to dissolve in it; becoming *liquid* on exposure to air.
- delta connection** A method of connecting the three windings of a three-phase electrical system. The windings are connected in series, the three-phase supply being taken from, or put into, the three junctions.
- delta-iron** An allotropic (see *allotropy*) form of pure iron that exists between 1400°C . and the *melting point*.
- delta metal** An *alloy* of copper (55%) and zinc (43%) with small amounts of iron and other *metals*.
- delta ray** An *electron* ejected from an *atom* by a fast moving ionizing particle.
- demagnetization** The process of depriving a body of its magnetic properties. The 'demagnetization energy' is the *energy* that would be released when a body is completely demagnetized.
- demodulation** The process, in a *radio*, *television*, or *radar* receiver, of separating information from a *modulated carrier wave*. The equipment used is called a demodulator or a *detector*.
- denature 1.** To denature *ethanol* is to add some poisonous substance to it to make it unfit for human consumption, e.g. *methylated spirits*. 2. To denature a *fissile* material is to add another *isotope* to it to render it unsuitable for use in a *nuclear weapon*. 3. To denature a *soluble*, or globular, *protein* is to produce a structural change in it,

DENDRITE

either chemically or by heating, so that it loses most of its solubility. Usually involves an unfolding of the *polypeptide* chain.

dendrite 1. (chem.) A many-branched *crystal*. 2. (bio.) The branching processes of a *neurone* that carry impulses into the *cell* body and form *synapses* with the *axons* of other neurones.

dendrology The branch of *botany* concerned with trees and shrubs.

denitrifying bacteria *Bacteria* in the *soil* that, in the absence of oxygen, break down *nitrates* and *nitrites* with the evolution of free nitrogen.

denominator (math.) The number below the line in a *vulgar fraction*, e.g. 4 in $\frac{3}{4}$.

densitometer An instrument for the measurement of the *density* of an image produced by *light*, *X-rays*, *gamma rays*, etc., on a photographic plate.

density The mass of unit *volume* of a substance. In *SI units* density is expressed in *kilograms* per cubic metre, in *c.g.s. units* in *grams* per cubic centimetre, and in *f.p.s. units* in *pounds* per cubic foot. $1 \text{ kg m}^{-3} = 10^{-3} \text{ g cm}^{-3} = 0.062\,428 \text{ lb ft}^{-3}$. See also *relative density*; *vapour density*.

density, optical If one medium has a greater *refractive index* than another for *light* of a given *wavelength*, then it has the greater optical density for that wavelength.

density, photographic The degree of *opacity* of a part of a *negative* or transparency.

deoxyribonucleic (desoxyribosenucleic) acid DNA. Long thread-like *molecules* found in *chromosomes* and some *viruses*, consisting of two interwound helical chains of *polynucleotides*. The *sugar* of all the *nucleotides* is 2-deoxy-D-*ribose*, but each nucleotide is characterized by one of the four following nitrogenous bases: *adenine*, *cytosine*, *guanine*, and *thymine*. DNA molecules are responsible for storing the *genetic code* by the order of the arrangement of their nitrogenous bases, three bases coding for one *amino acid*. The structure of a DNA molecule has been likened to a twisted rope-ladder, the sides of which consist of sugarphosphate chains, the rungs of linked nitrogenous bases. The rungs consist of complementary base pairs linked by *hydrogen bonds*.

depilatory A substance used for removing hair.

depleted material In general, a material that contains less of a particular *isotope* than it normally possesses. In particular, applied to *nuclear fuel*, a material that contains less *fissile* isotopes than natural uranium, e.g. the residue from an *isotope separation* plant or a *nuclear reactor*.

depletion layer The region of a *semiconductor* in which the density of mobile *carriers* is too low to neutralize the fixed charge density of *donors* and *acceptors*.

depolarization The prevention of electrical *polarization* in a *cell*. In the *Leclanché cell* polarization is reduced by surrounding the positive

carbon pole with *manganese dioxide*, MnO_2 . This oxidizes the hydrogen liberated at the pole, the chief cause of polarization.

depolymerization The breaking down of *polymers* into their original *monomers*; the reverse of *polymerization*.

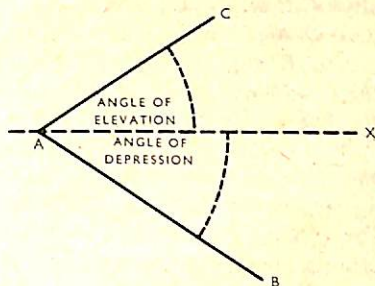


Figure 11.

depression, angle of If *B* is a point below the level of another point *A*, the angle of depression of *B* from *A* is the angle that *AB* makes with the horizontal plane *AX* through *A*. See Fig. 11.

depression of freezing point Lowering of the *freezing point* of a liquid when a *solid* is dissolved in it. With certain exceptions, the depression is proportional to the number of *molecules* or *ions* present, and the depression produced by the same *molecular concentration* of any substance is a constant for a given *solvent*. This gives rise to the *cryoscopic method* for the determination of *molecular weights*.

depth of field Depth of focus. The range over which a camera, or other optical instrument, will produce a distinct *image* of an object.

derivative (chem.) A *compound* derived from (but not necessarily prepared from) some other compound, usually retaining the general structure of the parent compound; e.g. *nitrobenzene*, $\text{C}_6\text{H}_5\text{NO}_2$, is a derivative of *benzene*, C_6H_6 , one *hydrogen atom* in the *molecule* of the latter being replaced by a *nitro group*.

derivative (math.) Derived function. The result of *differentiation* of a mathematical function. See Appendix, Table 9.

derived unit See *base unit*.

desalination The process of removing salt from sea-water to make it suitable for agricultural purposes or for drinking. Various methods are possible, but to make the process commercially viable on a large scale, the waste heat from a *nuclear power station* is used to provide the *energy* for *distillation*. In some countries *solar energy* can also be used.

desiccation Drying; removal of moisture.

desiccator An apparatus used in laboratories for drying substances and for preventing *hygroscopic* substances from picking up moisture. It consists of a glass vessel, with a close-fitting ground lid, that

DESORPTION

contains some hygroscopic substance, e.g. *phosphorus pentoxide*, P_2O_5 .

desorption The removal of *molecules*, *ions*, etc., from the surface of a solid so that they become gaseous; the reverse of *adsorption*.

destructive distillation Carbonization. Heating a complex substance to produce chemical changes in it, and distilling off the *volatile* substances so formed. E.g. the destructive distillation of *coal* produces *coal-gas* and many other valuable products.

detector That part of a *radio* receiver in which the information is separated from the *modulated carrier wave*. Now more usually called a demodulator. See *demodulation*, also *crystal detector*.

detergents Cleaning agents; products used in *solution* for washing or cleaning by action other than simple dissolution, usually with the aid of *surface-active agents*. Modern synthetic detergents, as distinct from *soaps*, are compounds such as *alkylarene sulphonates*, sulphated *aliphatic alcohols*, etc. Unlike soaps, they are effective in *hard water* and do not form a scum.

determinants An algebraic method of solving *simultaneous equations* in which an expression is written out in a square array. Thus, the determinant of $a_1b_2 - a_2b_1$ is written:

$$\begin{vmatrix} a_1b_1 & a_1b_2 \\ a_2b_1 & a_2b_2 \end{vmatrix}$$

detinning The recovery of metallic tin from scrap tin-plate by the action of chlorine, which combines with the tin to form *volatile stannic chloride*, $SnCl_4$.

detonating gas A *mixture* of hydrogen and oxygen in a *volume* ratio of 2:1; i.e. in the volume ratio required to form *water*. It is extremely explosive when ignited.

detonation Extremely rapid *combustion* that takes place within a high velocity *shock wave*. Also used loosely to describe the combustion reactions that occur during *knocking* or 'pinking' in an *internal-combustion engine*.

deuterium D. 2_1H . The *isotope* of hydrogen with *mass number* 2, and *atomic mass* 2.0147. The *abundance* of deuterium in natural hydrogen is 0.0156%. It occurs in *water* as the oxide, D_2O (see *heavy water*), from which it is obtained by fractional *electrolysis*.

deuterium oxide D_2O . See *heavy water*.

deuteron The *nucleus* of the *deuterium atom*.

Devarda's alloy An alloy of 50% copper, 45% aluminium, and 5% zinc.

developing, photographic The action of certain chemicals, usually organic *reducing agents*, on an exposed photographic plate or film in order to bring out the latent image. The developer reduces those areas of the silver *salts* that had been exposed to *light* to metallic silver. This remains as a black deposit. See *photography*.

DEWAR FLASK

deviation (statistics) The difference between one of a set of values and the *mean* of the set. The 'mean deviation' is the mean of all the individual deviations of the set.

deviation, angle of The difference between the angle of *incidence* and the angle of *refraction* when a ray of *light* passes from one medium to another. See Fig. 13 under *dispersion of light*.

devitrification of glass. The crystallization of *glass*, which is normally an *amorphous* mixture in a *metastable* state; when crystallization takes place, the glass loses its characteristic state of clear transparency.

dew Liquid water produced by *condensation* of water vapour in the air when the *temperature* falls sufficiently for the vapour to reach saturation.

MODERN THERMOS FLASK

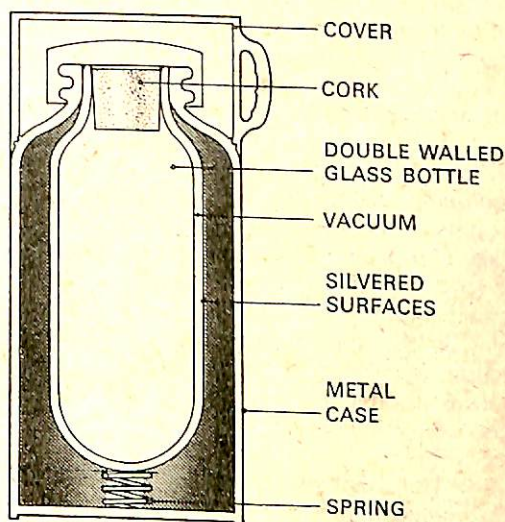


Figure 12.

Dewar flask A glass vessel used for keeping *liquids* at *temperatures* differing from that of the surrounding air. This is done by reducing to a minimum the transfer of *heat* between the liquid and the air. It consists of a double-walled flask with the space between the two walls exhausted to a very high *vacuum*, to minimize transfer of heat by *convection* and *conduction*. The inner surfaces of the walls are silvered to reduce transfer of heat by *radiation*; areas of contact

DEW POINT

between the two walls are kept at a minimum to keep down conduction of heat. See Fig. 12. Named after James Dewar (1842-1913).

dew point The *temperature* at which the *water vapour* present in the air saturates the air and begins to condense, i.e. *dew* begins to form.

dextrin British gum, starch gum. A *mixture* of gummy *polysaccharide carbohydrates* obtained by the partial *hydrolysis* of *starch*.

dextrorotatory Rotating or deviating the plane of vibration of polarized light to the right (observer looking against the oncoming light). See *polarization of light*.

dextrose See *glucose*.

diacetyl See *butanedione*.

diagonal A line joining the intersections of two pairs of sides of a *rectilinear* figure.

dialysis The separation of *colloids* in *solution* from other dissolved substances by selective *diffusion* through a *semipermeable membrane*. Such a membrane is slightly permeable to the *molecules* of the dissolved substances, but not to the larger molecules or groups of molecules in the colloidal state.

dialyzed iron A *colloidal solution* of ferric hydroxide, $\text{Fe}(\text{OH})_3$. A deep red liquid, used in medicine.

dialyzer An arrangement for effecting *dialysis*. The *solution* to be dialyzed is placed in a vessel in which it is separated from *water* by a *semipermeable membrane*; this is not permeable to the substance in the *colloidal state*, which will eventually remain as a pure solution on its side of the membrane.

diamagnetism The property of a substance that has a small negative *magnetic susceptibility*. This type of magnetism is due to a change in the orbital motion of the *electrons* in the *atoms* of the substance consequent on the application of an external *magnetic field*. The phenomenon occurs in all substances, although the resulting diamagnetism is often masked by the much greater effects due to *paramagnetism* or *ferromagnetism*.

diameter See *circle*.

diaminohexane Hexamethylenediamine. $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$. A *soluble* organic substance, m.p. 41.2°C ., b.p. 204°C ., used in the manufacture of *nylon*.

diamond A natural crystalline allotropic form (see *allotropy*) of carbon. It is colourless when pure, but is sometimes coloured by traces of impurities; it has a very high *refractive index* and *dispersive power*. Diamond is one of the hardest substances known (owing to the *covalent bonds* between the atoms in its crystals) and is transparent to *X-rays* (imitations are not). Used for cutting tools and drills, and as a gem.

diastase An *enzyme* contained in *malt*, which converts *starch* into *maltose* during *brewing*. See also *amylase*.

diathermancy The property of being able to transmit *heat radiation*; it is similar to transparency with respect to *light*.

diathermy A method of medical treatment by heating the body-tissues by the passage of a *high-frequency* electric discharge.

diatomaceous earth See *kieselguhr*.

diatomic (chem.) Consisting of two *atoms* in a *molecule*; e.g. hydrogen gas, H_2 .

diazo compounds Like *azo compounds*, diazo compounds contain two adjacent nitrogen atoms, which may form an *azo group*, but only one is attached to a carbon atom; e.g., benzenediazonium chloride $C_6H_5-N^+ \equiv N Cl^-$, *diazomethane* $CH_2 = N \equiv N$ denotes a *coordinate* (dative) *bond*], and benzenediazohydroxide, $C_6H_5.N:N.OH$. *Aromatic* diazo compounds are of great importance; by *azo coupling* they give *azo compounds* used as dyes, drugs, etc. They are prepared from aromatic amines containing $-NH_2$ groups, the simplest of which is *aniline*. A salt of the amine is treated with *nitrous acid*, which converts $-NH_2$ into the *diazonium* group, $-N^+ \equiv N$, a process known as *diazotization*. The resulting *diazonium* salt can be used for *azo coupling*.

diazomethane CH_2N_2 . A highly poisonous and explosive yellow gas. Used as a methylating agent and prepared for this purpose as required, usually in solution.

diazonium compounds *Organic compounds* of the general formula $RN_2^+X^-$, where R is an aryl radical, RN_2^+ is a *cation*, and X^- is an *anion*. E.g. benzenediazonium chloride, $C_6H_5N_2^+Cl^-$, is a typical *diazonium salt*. Diazonium salts are prepared by *diazotization* (see *diazo compounds*) of *amines*, an important stage in the production of *azo dyes*.

dibasic acid. An *acid* containing two *atoms* of *acidic hydrogen* in a *molecule*; an acid giving rise to two series of *salts*, normal and acid salts; e.g. *sulphuric acid*, H_2SO_4 , which gives rise to normal *sulphates* and hydrogen *sulphates* or *bisulphates*.

dibromoethane Ethylene dibromide. $C_2H_4Br_2$. A *volatile liquid* existing in two *isomeric* forms. The common isomer 1,2-dibromoethane, m.p. $10^\circ C.$, b.p. $131^\circ C.$, is used in conjunction with anti-knock compounds in *petrol* and as a *solvent*.

dibutyl oxalate $(C_4H_9OOC)_2$. A colourless *liquid*, b.p. $243.4^\circ C.$, used as a *solvent* and in organic synthesis.

dichlorodifluoromethane CCl_2F_2 . A colourless gas, b.p. $-29^\circ C.$, used as a *refrigerant* and as a *propellant* for *aerosols*.

dichloroethane. Ethylene dichloride, Dutch liquid. $C_2H_4Cl_2$. An oily toxic *liquid* existing in two *isomeric* forms. The common isomer 1,2-dichloroethane, m.p. $-35^\circ C.$, b.p. $84^\circ C.$, is used as a *solvent* and in the manufacture of *polyvinyl chloride*.

dichloromethane Methylene chloride. CH_2Cl_2 . A colourless *volatile*

DICHROISM

liquid, b.p. 40.1°C., used as a *solvent*, a *refrigerant*, and an *anaesthetic*.

dichroism The property of some *crystals*, such as *tourmaline*, that makes them appear different colours if light falls on them from different directions. It is caused by a difference in the extent to which the *ordinary ray* and the *extraordinary ray* are absorbed.

dichromate A *salt* of the hypothetical dichromic acid, $\text{H}_2\text{Cr}_2\text{O}_7$, e.g. *potassium dichromate*, $\text{K}_2\text{Cr}_2\text{O}_7$.

dichromate cell Bichromate cell. A *primary cell* having a positive pole of carbon and a negative pole of zinc in a *liquid* consisting of a *solution* of *sulphuric acid*, H_2SO_4 , and *potassium dichromate*, $\text{K}_2\text{Cr}_2\text{O}_7$, the latter acting as a depolarizing agent (see *depolarization*) by its oxidizing action. The *EMF* is 2.03 volts.

dichromatism A form of colour blindness in which only two *colours* of the *spectrum* can be distinguished.

dicyanodiamide Cyanoguanidine. $\text{H}_2\text{NC}(\text{NH})\text{NHCN}$. A white crystalline substance, m.p. 208°C., used in the manufacture of *melamine* and of *barbiturates* and other drugs.

dielectric Non-conductor of electricity, insulator. A substance in which an *electric field* gives rise to no net flow of *electric charge* but only to a displacement of charge.

dielectric constant See *permittivity*.

dielectric heating A form of heating in which electrically insulating material is heated by being subjected to an alternating *electric field*. It results from *energy* being lost by the field to *electrons* within the *atoms* and *molecules* of the material. In industrial dielectric heating the material to be heated is placed between the plates of a *capacitor* connected to a *high frequency* power source.

dielectric strength The maximum *voltage* that can be applied to a *dielectric* material without causing it to break down; usually expressed in *volts* per mm. See table under *permittivity* for the dielectric strengths of some common dielectric materials.

dielectrophoresis The motion of electrically polarized (see *electric polarization*) particles in a non-uniform *electric field*.

Diels-Alder reaction A method of preparing a *benzene ring* from a *diene* and a compound containing a single *double bond* (e.g. *maleic acid*). Named after Otto Diels (1876-1954) and Kurt Alder (1902-1958).

diene An *unsaturated hydrocarbon* containing two *double bonds*, e.g. *butadiene*.

Diesel engine A type of *internal-combustion engine* that burns heavy oil. A mixture of air and oil is compressed and thereby heated to the *ignition temperature* of the oil (about 540°C.). Named after Rudolf Diesel (1858-1913).

diethylamine $(\text{C}_2\text{H}_5)_2\text{NH}$. A colourless liquid with a smell resembling

ammonia, b.p. 55°C., used in pharmaceuticals and in the rubber industry.

diethyl ether See *ethers*.

differential calculus A branch of mathematics that deals with continuously varying quantities. It is based upon the *differential coefficient* of one quantity with respect to another of which it is a *function*. Used for solving problems involving the rates at which processes occur and for obtaining maximum and minimum values for continuously varying quantities.

differential coefficient Derived function, derivative. See *differentiation* and Appendix, Table 9.

differential equation An equation that involves *differential coefficients*. An ordinary differential equation is one in which only one independent variable is involved. The *order* of a differential equation is the same as that of the *derivative* of the highest order appearing in it; the *degree* is given by the largest *exponent*.

differentiation (bio.) 1. The development of *cells* so that they are capable of performing specialized functions in the organs and *tissues* of the *organisms* to which they belong. 2. In microscopic specimens, the removal of the excess stain from certain parts to show up the structure of the whole.

differentiation (math.) The operation, used in the *calculus*, of obtaining the *differential coefficient*; if $y = x^n$, the differential coefficient, $dy/dx = nx^{n-1}$. See Appendix, Table 9.

diffraction When a beam of *light* passes through an *aperture* or past the edge of an opaque obstacle and is allowed to fall upon a screen, patterns of light and dark bands (with *monochromatic light*) or coloured bands (with *white light*) are observed near the edges of the beam, and extend into the geometrical shadow. This phenomenon, which is a particular case of *interference*, is due to the wave nature of light, and is known as diffraction. The phenomenon is common to all *wave motions*. See also *electron diffraction*.

diffraction grating A device used to disperse a beam of *light*, X-rays, or other *electromagnetic radiation* into its constituent *wavelengths*, i.e. for producing its *spectrum*. It may consist of any device that acts upon an incident *wave front* in a manner similar to that of a regular array of parallel slits where the slit width is of the same order as the wavelength of the incident radiation. Such gratings may be prepared by ruling equidistant parallel lines on to a *glass* (transmission grating) or *metal surface* (reflecting grating). The grating may be plane or concave, the latter having self-focusing properties.

diffusion of gases *Molecules* of all gases move freely and tend to distribute themselves equally within the limits of the vessel enclosing the gas; thus all gases diffuse within the limits of any enclosing walls, and are all perfectly miscible with one another. The rates of

DIFFUSION OF LIGHT

- diffusion of gases through porous bodies are inversely proportional to the square roots of their *densities*. (See *Graham's Law*.)
- diffusion of light** The *scattering* or alteration of direction of *light* rays, as produced by transmission through frosted glass, fog, etc., or by irregular reflections at matt surfaces such as blotting paper.
- diffusion of particles** In *nuclear physics*, the passage of *elementary particles* through *matter* in such a way that the *probability* of *scattering* is large compared to that of *capture*.
- diffusion of solutions** *Molecules* or *ions* of a dissolved substance move freely through the *solvent*, the *solution* becoming uniform in *concentration*; the phenomenon is similar to *diffusion of gases*.
- diffusion plant** A plant for separating *isotopes*, based on their different rates of *diffusion* in the gaseous state through a membrane.
- diffusion pump** See *condensation pump*.
- digit** (astr.) One twelfth of the diameter of the *Sun* or *Moon*; used to denote the extent of an *eclipse*.
- digit** (math.) A single figure or numeral; e.g. 325 is a number of 3 digits.
- digital computer** A *computer* that operates on data in the form of *digits*, rather than the physical quantities used in *analog computers*. Originally mechanical devices employing cogs, gears, and levers, they now depend upon *electronic* techniques that allow computers to be constructed capable of dealing automatically with a very wide range of problems at very high speeds. Modern digital computers are usually based on the *binary notation*, numbers and letters being coded into groups of digits consisting only of 1 or 0. Each of these digits is represented in an electronic circuit or magnetic store by a component in an on or off state (e.g. passing current or not passing current, magnetized or not magnetized). Data in this form is processed in the *C.P.U.* of the computer by *gates* (switches), which obey the instructions of the *program*. The program is also held in the store of the *C.P.U.* in binary form.
- digital display** A method of indicating the reading of a measuring instrument (e.g. a *voltmeter*), clock, etc., in which numbers appear on a screen, as opposed to a pointer moving round a scale. It is often based on a *digitron* or a *light-emitting diode*. See also *liquid-crystal display*.
- digitalis** A *mixture* of *glucosides* of vegetable origin (e.g. *digitonin*, *digitoxin*), used in the treatment of certain heart conditions.
- digitoxin** $C_{41}H_{64}O_{13}$. A white crystalline *glucoside*, m.p. 252–3°C., obtained from *digitalis* and used as a heart stimulant.
- digitron** A vacuum tube used to give a *digital display* of a numerical value. It has *cathodes* shaped to form the digits 0–9.
- dihedral** Formed by two intersecting *planes*.
- dihydric** (chem.) Containing two *hydroxyl* groups in a molecule; e.g. a *diol*.

dilatancy The tendency of some *colloidal* materials to solidify or become more rigid under pressure. Compare *thixotropy*.

dilation Dilatation (phys.). A change in *volume*.

dilatometer An apparatus used for measuring *volume* changes of substances. It generally consists of a bulb with a graduated capillary stem.

dilute Containing a large amount of *solvent*, generally *water*. 'Dilute' laboratory solutions of *reagents* are generally of twice *normal* strength, containing 2 *gram-equivalents* per litre.

dilution 1. The further addition of *water* or other *solvent* to a *solution*.
2. The *reciprocal* of *concentration*; the *volume* of *solvent* in which unit quantity of *solute* is dissolved.

dimensions of units The dimensions of a physical quantity are the *powers* to which the *fundamental units* (length *l*, mass *m*, time *t*, etc.) expressing that quantity are raised. E.g. *volume*, l^3 , is of dimensions three in length; *velocity*, i.e. length per unit time, l/t , is of dimensions one in length and -1 in time.

dimer A substance composed of *molecules* each of which comprises two molecules of a *monomer*.

dimethoxymethane Methylal. $(CH_3O)_2CH_2$. A colourless inflammable *liquid*, b.p. $45.5^\circ C.$, used as a *solvent* and in perfumes.

dimorphism The existence of a substance in two different crystalline forms.

dimorphous Existing in two different crystalline forms.

di-neutron An unstable system comprising two *neutrons*.

dinitrobenzene $C_6H_4(NO_2)_2$. A colourless *insoluble* crystalline substance that exists in three *isomeric* forms, the most important of which is the *meta-form*, m.p. $90^\circ C.$, which is used in the manufacture of *dyes*.

dinitrogen tetroxide See *nitrogen dioxide*.

diode A *thermionic valve* containing two *electrodes*, *anode* and *cathode*. The diode is used chiefly for *rectification* and *demodulation*. Modern diodes consist of a P-N *semiconductor junction*.

diols Glycols. *Dihydric alcohols* derived from *aliphatic hydrocarbons* by the substitution of *hydroxyl groups* for two of the hydrogen atoms in the *molecule*. General formula $C_nH_{2n}(OH)_2$. See also *ethanediol*.

diopetre Unit of power of a *lens*; the power of a lens in dioptries is the *reciprocal* of its *focal length* in *metres*. The power of a *converging lens* is usually taken to be positive, that of a *diverging lens* negative.

dioxane Diethylene dioxide. $(C_2H_4)_2O_2$. A colourless inflammable *liquid cyclic ether*, b.p. $101^\circ C.$, used as a *solvent* and a *dehydrating agent*.

dip, magnetic See *magnetic dip*.

DIP CIRCLE

dip circle Inclinator. An instrument for measuring the *angle* of *magnetic dip*. It consists of a magnetized needle mounted to rotate in a vertical plane, the angle being measured on a circular scale, marked in degrees.

dipeptide A *peptide* consisting of two *amino acids*.

diphenylamine (C_6H_5)₂NH. A colourless crystalline substance, m.p. 52.8°C., used in the manufacture of *dyes* and in analytical chemistry as a detector of *oxidizing agents*.

diploid cell A *cell* in which the *nucleus* contains *chromosomes* in pairs. Nearly all animal cells are diploid, except *gametes*. See *haploid*.

dipole 1. Two equal point *electric charges* (electric dipole) or *magnetic poles* (magnetic dipole) of opposite sign, separated by a small distance. The dipole moment is the product of either charge (or pole) and the distance between the two. It may also be expressed as the *couple* that would be required to maintain the dipole at right angles to a *field* electric or magnetic) of unit intensity. *Molecules* in which the centres of positive and negative *charge* are separated constitute dipoles, the dipole moments of which are measured by *Debye units* or *coulomb metres*. Dipole moments can often provide evidence as to the shape of molecules, e.g. *water* has a dipole moment of 1.85 Debye units (6.1×10^{-30} Cm), which indicates that it is triangular in shape with an angle of 105° between the two O-H bonds. 2. A *radio aerial* consisting of two rods.

dipole moment See *dipole*.

dippel's oil See *bone oil*.

di-proton An unstable system comprising two *protons*.

direct current d.c. An *electric current* flowing always in the same direction.

direct dyes Cotton dyes, substantive dyes. A group of *dyes* that dye cotton, viscose rayon, and other *cellulose* fibres direct, without the use of *mordants*. Generally used with 'assistants' such as common salt or *sodium sulphate*, which assist absorption by the fibre.

direct motion (astr.) 1. The motion of a *planet* or other celestial body round the *Sun* in the same direction as the *Earth*. All the planets have direct motion, but some *comets* and *satellites* do not, and they are said to have 'retrograde motion'. 2. Motion across the sky from west to east.

directrix A fixed line used to describe and define a curve, by relating the distance of a point on the curve to this line and to the *focus* of the curve. See *parabola* and *hyperbola*.

direct vision spectroscope A *spectroscope* designed for compactness and portability. In this instrument, the middle portion of the *spectrum* (the yellow) remains undeviated. The eye thus looks in the direction of the source when observing the spectrum.

disaccharides. A group of *sugars* the *molecules* of which are derived by the *condensation* of two *monosaccharide* molecules with the

elimination of a molecule of water. On *hydrolysis* disaccharides yield the corresponding monosaccharides. E.g. *cane-sugar*, sucrose, $C_{12}H_{22}O_{11}$, is a disaccharide which, on hydrolysis with dilute acids, gives a *mixture* of *glucose* and *fructose*, both monosaccharides having the formula $C_6H_{12}O_6$. (See *inversion of cane-sugar*). Other important disaccharides are *lactose* and *maltose*.

discharge, electrical 1. The release of the *electric charge* stored in a *capacitor* through an external circuit. 2. The conversion of the *chemical energy* stored in an *electric cell* into *electrical energy*.

discharge in gases The passage of *electricity* through a tube containing a gas at low pressure. *Electrons* and *ions* present in the tube are accelerated towards their respective *electrodes* by the applied *potential difference*, the net transfer of *electric charge* constituting the current. The electrons are accelerated sufficiently to produce ions by collision with the gas *molecules*. Re-combination of oppositely charged ions gives rise to luminous glows at certain parts of the tube. The study of this phenomenon has led to many important results, including the discovery of the electron and of *isotopes*.

discriminator An *electronic* circuit that converts *frequency* or *phase modulation* into *amplitude modulation*.

disinfectant A substance capable of destroying disease *bacteria*.

disintegration (phys.) Any process in which the *nucleus* of an *atom* emits one or more particles or *photons*, either due to spontaneous *radioactivity* or as the result of a collision.

disintegration constant Decay Constant. Transformation Constant. The *probability* of the *decay* of an atomic *nucleus* per unit time that characterizes a *radioactive isotope*. It determines the exponential decrease with time, t , of the *activity*, A , given by:

$$A = A_0 e^{-\lambda t}$$

where A_0 is the activity when $t = 0$, and λ is the disintegration constant.

dislocation A line *defect* in a *crystal*, the result of a slip along a surface of one or more *lattice* constants.

disordering The displacement of *atoms* from their position in a *crystal lattice* (e.g. as a result of the effect of *ionizing radiation*) to positions that are not part of the lattice.

disperse dyes Dyes of all chemical types that are applied in the form of fine suspensions in water to man-made fibres, such as *cellulose acetate*, *nylon*, and *polyester* fibres. They are insoluble in water, but are usually soluble in organic solvents, such as *esters*.

disperse phase The dissolved or suspended substance in a *colloidal solution* or *suspension*.

dispersion (chem.) A *disperse phase* suspended in a *disperse medium*;

DISPERSION MEDIUM

a system of particles dispersed and suspended in a *solid*, *liquid*, or *gas*.

dispersion medium A medium in which a substance in the *colloidal state* is dispersed; the *solvent* in a *colloidal solution*.

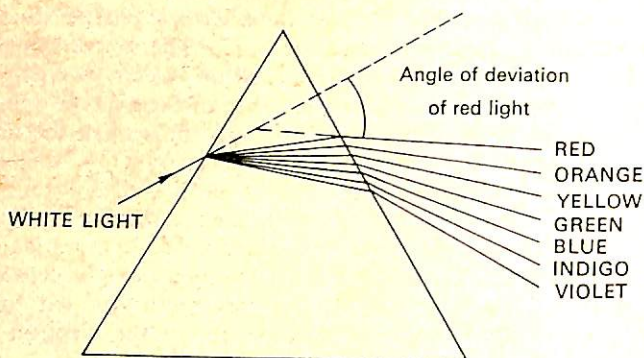


Figure 13.

dispersion of light The splitting of *light* of mixed wavelengths into a *spectrum*. A beam of ordinary *white light*, e.g. sunlight, on passing through an optical *prism* or a *diffraction grating*, is divided up or dispersed into light of the different wavelengths of which it is composed; if the beam that emerges after dispersion is allowed to fall upon a screen, a coloured band or spectrum is observed. Dispersion by a prism is due to the fact that lightwaves of different wavelengths are refracted (see *refraction*) or bent through different angles on passing through the prism, and are thus separated. See Fig. 13.

dispersive power of a medium. A measure of the *dispersion of light* produced by a *prism* or a particular medium with respect to light of two specified *wavelengths* ('1' and '2'); given by the ratio

$$(n_1 - n_2)/(n - 1)$$

where n_1 is the *refractive index* of the medium for wavelength 1, n_2 that for wavelength 2, and n is the average of n_1 and n_2 . When considering the dispersive power of media for ordinary *white light*, the dispersive power is often defined as

$$n_b - n_r/n_y - 1$$

where n_b , n_r , and n_y are the refractive indices for blue, red, and yellow light respectively.

dissociation (chem.) A temporary, reversible *decomposition* of the *molecules* of a *compound*, which occurs under some particular

- conditions. In *electrolytic dissociation*, the molecules are split into *ions* (see *ionic hypothesis*). In *thermal dissociation*, the effect of *heat* is to decompose a definite fraction of the molecules; e.g. *ammonium chloride*, NH_4Cl , dissociates into *ammonia*, NH_3 , and *hydrogen chloride*, HCl , on heating. The products recombine on cooling, and the degree of dissociation depends on the *temperature*. The ratio of the product of the *active masses* of the molecules resulting from the dissociation, to the active mass of the undissociated molecules, when *chemical equilibrium* has been reached under a particular set of physical conditions, is called the 'dissociation constant'. See also *equilibrium constant*.
- dissociation constant** See *dissociation*.
- distillate** The *liquid* obtained by the *condensation* of the vapour in *distillation*.
- distillation** The process of converting a *liquid* into *vapour*, condensing the vapour, and collecting liquid or *distillate*. Used for separating *mixtures* of liquids of different *boiling points* or for separating a pure liquid from a non-volatile constituent. (See *fractional distillation*). Also used in the separation of *isotopes*. See *isotopes*, *separation of*.
- distilled water** Water that has been purified by *distillation* of the substances dissolved in it.
- diurnal** Daily; performed or completed once every 24 hours.
- divalent** Bivalent. Having a *valence* of two.
- divergent** Going away in different directions from a common path or point.
- diverging lens** A *lens* that causes a parallel *beam* of *light* passing through it to diverge or spread out; *concave lens*. See Fig. 25 under *lens*.
- Divers' liquid** A solution of *ammonium nitrate* in liquid *ammonia*. Used as a *solvent* for some *metals* and their *oxides* and *hydroxides*.
- divinyl ether** Vinyl ether. $\text{H}_2\text{C}:\text{CHOCH}:\text{CH}_2$. A colourless inflammable *liquid*, b.p. 39°C ., used as an *anaesthetic*.
- division** An arithmetic operation in which a dividend is divided by a divisor to give a quotient and a remainder.
- DNA** See *deoxyribonucleic acid*.
- docosanoic acid** Behenic acid. $\text{CH}_3(\text{CH}_2)_{20}\text{COOH}$. A crystalline *saturated fatty acid*, m.p. 80°C ., used in the manufacture of *cosmetics* and *waxes*, and as a *plasticizer*.
- dodecahedron** A *polyhedron* with twelve faces.
- dodecanal** See *lauraldehyde*.
- dodecanoic acid** See *lauric acid*.
- dodecanol** See *lauryl alcohol*.
- dolomite** Pearl spar. Natural double *carbonate* of magnesium and calcium, $\text{MgCO}_3\cdot\text{CaCO}_3$. A whitish solid that occurs naturally in vast amounts, comprising whole mountain ranges.

DONOR

donor An imperfection in a *semiconductor* that causes *electron* conduction.

doping The addition of a small quantity of impurity to a *semiconductor* to achieve a particular characteristic.

Doppler broadening The broadening of spectral emission or absorption lines (see *spectrum*) due to random motion of the emitting or absorbing *molecules*, *atoms*, or *nuclei*. See *Doppler effect*.

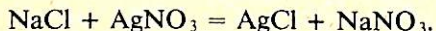
Doppler effect Doppler shift. Doppler's principle. The apparent change in the *frequency* of sound or *electromagnetic radiation* due to relative motion between the source and the observer. The *pitch* (*frequency*) of the sound emitted by a moving object (e.g. the whistle of a moving train) appears to a stationary observer to increase as the object approaches him and to decrease as it recedes from him. The *light* emitted by a moving object appears more red (red light being of lower frequency than the other colours) when it is receding from the observer (or the observer receding from it). Thus the fact that the light emitted by the *stars* of distant *galaxies* suffers a *red shift*, when observed from the Earth, is taken to mean that these distant galaxies are receding from our *Galaxy*. This is the principal evidence for the widely accepted hypothesis concerning the *expansion of the Universe*. The Doppler effect is also used in *radar*, to distinguish between stationary and moving targets and to provide information concerning their *velocity*, by measuring the frequency shift between the emitted and the reflected radiation. Named after C. J. Doppler (1803-53).

dose (phys.) The 'absorbed dose' is the *energy* imparted by *ionizing radiation* to unit *mass* of irradiated *matter*. Measured in *rads* (i.e. 100 *ergs* per gram or 0.01 *joule* per *kilogram*). The 'maximum permissible dose (or level)' is the recommended upper limit for the absorbed dose that a person should receive during a specified period.

dosimeter A device for measuring a *dose* of *ionizing radiation*. Several methods are used, including *ionization chambers*, the blackening of photographic film, and the extent to which a chemical reaction in solution proceeds.

double bond (chem.) Two *covalent bonds* linking two *atoms* in a chemical *compound*; characteristic of an *unsaturated compound*.

double decomposition (chem.) Metathesis. A *chemical reaction* between two *compounds* in which each of the original compounds is decomposed and two new compounds are formed. E.g. the action of *sodium chloride* on *silver nitrate* according to the equation



double refraction. The formation of two refracted rays of *light* (see *refraction*) from a single incident ray; a property of certain *crystals*, notably calcite.

double salt A compound of two salts formed by *crystallization* from a *solution* containing both of them. When redissolved the double salt ionizes as two salts. For example, *potassium sulphate* and *aluminium sulphate* in solution together will crystallize as the double salt $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$.

double star Two stars held very close to each other as a result of their mutual gravitational attraction, which move through space together giving the appearance, to the naked eye, of being one star.

doublet A pair of associated lines in a *spectrum* characteristic of the *alkali metals*.

drachm, fluid British unit of volume ; 60 minims; 3.55 cm^3 .

drain The electrode is a *field-effect transistor* through which *charge carriers* leave the inter-electrode region.

drug 1. Any chemical substance used in medicine to cure or prevent disease. 2. A habit-forming *narcotic*; any substance that causes physiological or emotional dependence.

dry cell Dry battery. A type of small *Leclanché cell* containing no free liquid. The *electrolyte* of *ammonium chloride* is in the form of a paste, and the negative zinc pole forms the outer container of the cell. Used for torch batteries, *radio* batteries, etc.

dry ice Solid *carbon dioxide*, CO_2 , used as a *refrigerant*.

drying oil An animal or vegetable oil that will harden to a tough film when a thin layer is exposed to the air. The hardening is due to *oxidation* or *polymerization* of the *unsaturated fatty acids* of which these oils partially consist. Used in *paints* and *varnishes* (e.g. *linseed oil*, *dehydrated castor oil*, and certain fish oils).

ductility A property, especially of *metals*, of being capable of being drawn out into a wire.

ductless glands Endocrine glands. Glands or organs producing *hormones* in the body.

Dulong and Petit's law For a *solid element*, the product of the *atomic weight* and the *specific heat capacity*, i.e. the *atomic heat*, is a constant, approximately equal to 25 joules per *mole*. For validity of this law, see *atomic heat*. Named after P. L. Dulong (1785-1838) and A. T. Petit (1791-1820).

duplet A pair of *electrons* shared between two atoms forming a single covalent bond. See *valence*, *electronic theory* of.

Duralumin* A light hard aluminium alloy containing about 4% copper, and small amounts of magnesium, manganese, and silicon.

dust core A core for magnetic devices made of powdered *metal* (often molybdenum) held together with a suitable binder. Particularly suitable for *high frequency* equipment.

Dutch liquid See *dichloroethane*.

Dutch metal An alloy of copper and zinc; a variety of *brass*.

dwarf star A star of small volume, high density, and usually low luminosity. See also *white dwarf star*.

DYAD

dyad (chem.) An *element* having a *valence* of two.

dyes Coloured substances that can be fixed firmly to a material to be dyed, so as to be more or less 'fast' to *water*, *light*, and *soap*. See *acid dyes*; *azo dyes*; *direct dyes*; *mordants*; *vat dyes*.

dynamic equilibrium. If two opposing processes are going on at the same rate in a system, thus keeping the system unchanged, the system is said to be in dynamic equilibrium. E.g. a *liquid* in equilibrium with its *saturated vapour*; the rate of *evaporation* from the liquid surface is equal to the rate of *condensation* of the *vapour*.

dynamics. A branch of *mechanics*; the mathematical and physical study of the behaviour of bodies under the action of *forces* that produce changes of motion in them.

dynamite An *explosive* consisting of *nitroglycerin* absorbed in *kieselguhr*.

dynamo A device for converting *mechanical energy* into *electrical energy*, depending on the fact that if an electrical *conductor* moves across a *magnetic field*, an *electric current* flows in the conductor. (See *induction*). The simplest form of dynamo consists of a powerful *electromagnet*, called the *field magnet*, between the *poles* of which a suitable conductor, usually in the form of a coil or coils, called the *armature*, is rotated. The mechanical energy of the rotation is thus converted into electrical energy in the form of a current in the armature.

dynamometer Any instrument designed for the measurement of *power*.

dynatron oscillator An oscillator, using a *tetrode* (screen grid valve) in such a way that the *anode current* increases as the *anode voltage* is reduced.

dyne C.G.S. system unit of *force*; the force that, acting upon a *mass* of 1 g, will impart to it an *acceleration* of 1 cm per second per second. 1 dyne = 10^{-5} newton = 7.233×10^{-5} poundal.

dysprosium Dy. Element. A.W. 162.50. At. No. 66. R.d. 8.556, m.p. 1407°C. See *lanthanides*.

dystectic mixture. A *mixture* that has a constant maximum *melting point*.

E

Earth A planet having its orbit between those of *Venus* and *Mars*. It is a sphere, slightly flattened towards the poles (i.e. approximating to an oblate *spheroid* in shape). Equatorial radius 6378.388 kilometres (3963.34 miles); polar radius 6356.912 kilometres (3949.99 miles). Mean density $5.52 \times 10^3 \text{ kg m}^{-3}$; mass $5.976 \times 10^{24} \text{ kg}$.

earthing a conductor. Making an electrical connection between the conductor and the Earth; the Earth is assumed to have zero potential.

Earth's crust Lithosphere. The Earth's outer layer of surface soil of varying thickness lying upon a mass of hard rock several miles thick. The approximate estimated percentages by weight of the chief chemical elements composing the Earth's crust are: oxygen 47%, silicon 28%, aluminium 8%, iron 4.5%, calcium 3.5%, sodium and potassium 2.5% each, magnesium 2.2%, titanium 0.5%; hydrogen 0.2%, carbon 0.2%, phosphorus and sulphur 0.1% each.

earthshine A faint illumination of the dark side of the *Moon* during a crescent phase, due to sunlight reflected from the Earth's surface.

Earth's magnetism See *magnetism, terrestrial*.

east-west asymmetry of cosmic rays The observed intensity of cosmic ray particles coming from the West is greater than that coming from the East at any given latitude. This asymmetry is due to the deflection of the primary charged cosmic ray particles by the magnetic field of the Earth, and indicates a preponderance of positively charged particles in the incoming radiation.

ebonite Vulcanite. A hard black insulating material made by vulcanizing rubber with high proportions of sulphur. Contains about 30% combined sulphur.

ebullition See *boiling*.

eccentricity 1. (math.) A constant used to describe a conic, equal to the distance from a point on the curve to the focus divided by the distance from that point to the directrix. 2. (astr.) A measure of the extent to which an ellipse is elongated, equal to the distance between the foci divided by the length of the major axis. This value is used to express the eccentricity of a planet's orbit round the Sun: e.g. the eccentricity of the Earth's orbit is 0.0167.

echelon (phys.) The type of grating that replaces the ordinary diffraction grating in spectroscopy when very high resolution is required. It consists essentially of a pile of plates of exactly equal thickness arranged in stepwise formation with a constant offset. The echelon can be used either as a transmission or as a reflection grating.

ECHO

echo The effect produced when *sound* or other *radiation* is reflected or thrown back on meeting a solid obstacle or a reflecting medium.

echolocation The location of an object by determining the direction of an *echo* reflected from it, or the time taken for the echo to return. E.g. *radar*, *echo sounding*, etc.

echo sounder A device for estimating the depth of the sea beneath a ship by measuring the time taken for a *sound* pulse to reach the sea bed and for its *echo* to return.

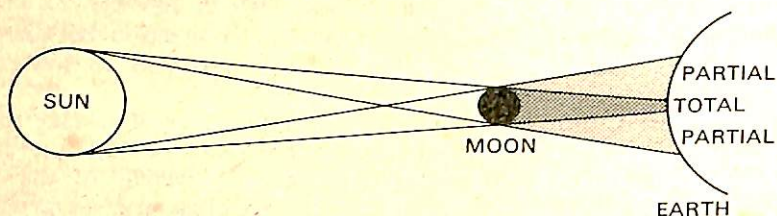


Figure 14.

eclipse The passage of a non-luminous body into the *shadow* of another. An 'eclipse of the *Moon*', or lunar eclipse, occurs when the *Sun*, the *Earth*, and the Moon are in line so that the shadow of the Earth falls upon the Moon. An 'eclipse of the *Sun*', or solar eclipse, is said to occur when the shadow of the Moon falls on the Earth. See Fig. 14, which also illustrates the areas of partial and total eclipse.

ecliptic The *Sun*'s apparent path in the sky relative to the *stars*; the circle described by the Sun on the *celestial sphere* in the course of a year.

ecology The study of the relation of plants and animals to their environment and to each other.

ecosphere 1. The part of the Earth's *atmosphere* in which life can exist: also called the 'biosphere' or 'physiological atmosphere'. 2. The part of the atmosphere surrounding any *planet* on which life could exist. 3. The part of *space* surrounding any *star* in which life could be possible.

ectoplasm The outer layer of the *cytoplasm* of a living *cell*. Usually a semi-solid *gel* containing relatively few granules.

eddy current heating See *induction heating*.

eddy currents Foucault currents. Induced (see *induction*) *electric currents* set up in the iron cores of *electromagnets* and other electrical apparatus. These currents cause considerable waste of *energy* in the cores of *armatures* of *dynamoes* and in *transformers*.

Edison accumulator* A nickel-iron *accumulator*. Named after T. A. Edison (1847-1931).

- EDTA** Ethylenediaminetetraacetic acid ($(\text{NCH}_2\text{CH}_2\text{N})_2(\text{HCOOCH}_2)_4$). An important chelating agent (see *chelation*), used generally in the form of the tetrasodium salt for *complexometric analysis*.
- effective resistance** The *resistance* of a *conductor* of electricity to *alternating currents*; in addition to the *direct current* resistance it includes the effect of any losses caused by the current (e.g. *eddy currents*). Measured by the ratio of the total loss to the square of the *root mean square* of the current.
- effective value** See *root mean square of an alternating quantity*.
- effervescence** The escape of small gas bubbles from a *liquid*, usually as the result of chemical action.
- efficiency of a machine** The ratio of the output *energy* to the input *energy*. The efficiency of a machine can never be greater than unity. Often expressed as a percentage.
- efflorescence** (chem.) The property of some crystalline *salts* of losing a part of their *water of crystallization*, and becoming powdery on the surface. E.g. crystals of *sodium carbonate*, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.
- effusion** (chem.) of gases. The passage of *gases* through small apertures under pressure. The relative rates of effusion of different gases under the same conditions are inversely proportional to the square roots of their *densities*.
- eigenfunction** An allowed *wave function* enabling a meaningful solution to be obtained from *Schrödinger's wave equation*. For each eigenfunction there is a set of fixed energy values (*eigenvalues*) in which the system can exist.
- einsteinium** Es. *Transuranic element*, At. No. 99. Most stable *isotope*, $^{254}_{99}\text{Es}$, has a *half-life* of 276 days.
- Einstein's equation** $E = mc^2$, where E is the energy equivalent of a mass m , and c is the *velocity of light*. A direct consequence of Einstein's special theory of *relativity*, this equation is the basis of all *nuclear energy*.
- Einstein shift** A slight displacement towards the red of the lines of the solar spectrum due to the *Sun's gravitational field*. Predicted by Einstein's general theory of *relativity* and subsequently verified experimentally. Named after Albert Einstein (1879-1955).
- elastance** The *reciprocal* of *capacitance*; measured in reciprocal *farads* or *darafs*.
- elastic collision** A collision between bodies under ideal conditions, such that their total *kinetic energy* before collision equals their total kinetic energy after collision. Referred to *nuclear physics*, an elastic collision is one in which an incoming particle is scattered without causing the *excitation* or breaking up of the struck *nucleus*.
- elastic cross-section** See *cross-section*.
- elasticity** The property of a body or material of resuming its original form and dimensions when the *forces* acting upon it are removed. If

ELASTIC LIMIT

the forces are sufficiently large for the deformation to cause a break in the molecular structure of the body or material, it loses its elasticity and the *elastic limit* is said to have been reached. *Hooke's law* applies only within the elastic limit. See also *elastic modulus*.

elastic limit The limit of *stress* within which the *strain* in a material completely disappears when the stress is removed.

elastic modulus Modulus of elasticity. The ratio of *stress* to *strain* in a given material. The strain may be a change in length (see *Young's modulus*), a twist or *shear* (see *rigidity modulus*), or a change in volume (see *bulk modulus*); the stress required to produce unit strain being in each case expressed in *newtons* per square metre or *dynes* per sq cm.

elastin Elastic fibrous *protein* found in the connective *tissues* of vertebrates.

elastomer A material that after being stretched will return to approximately its original length. Elastomers include *natural rubber*, *synthetic rubbers*, and rubberlike *plastics*.

electret A *dielectric* possessing a permanent electric *moment*.

electrical capacity See *capacitance*.

electrical condenser See *capacitor*.

electrical energy The *energy* associated with *electric charges* and their movements. Measured in *watt seconds* (*joules*) or *kilowatt-hours*. One kilowatt-hour equals 3.6×10^6 joules or $8.598 \ 45 \times 10^5$ calories.

electrical image A set of point charges on one side of a conducting surface that would produce the same *electric field* on the other side of the surface (in its absence) as the actual electrification of that surface.

electrical induction See *induction*.

electrical line of force A line in an *electric field* whose direction is everywhere that of the field.

electrical potential at a point The *work* necessary to bring unit positive *electric charge* from an infinite distance to that point. Analogous to a level; a positive charge would be driven from the points of higher to lower potential. The derived *SI unit* of electric potential is the *volt*. See also *potential difference*.

electric arc See *arc*.

electric-arc furnace A steel-making furnace in which an electric arc provides the source of heat. In direct-arc furnaces, the arc is formed between an electrode and the metal being heated. The Hérault furnace is an example of this type. Three graphite or amorphous-carbon electrodes are used and arcs form between each electrode and the metal charge. In the indirect-arc furnaces, heat is produced by a discharge between two electrodes and is radiated onto the charge. The Stassano furnace is an example of this type.

electric bell See *bell, electric*.

electric charge Science is unable to offer any explanation regarding the nature of an electric charge, but it is able to describe in some detail the properties of *matter* that is so charged. The *elementary particle* called an *electron* is said to be negatively charged with electricity, and the *proton* is said to be positively charged to an equal but opposite extent. These entities represent the basic units of electrically charged matter. Therefore, matter containing an equal number of protons and electrons is electrically neutral, but matter containing an excess of electrons possesses an overall negative charge; similarly matter that has a deficiency of electrons (i.e. an excess of protons) possesses an overall positive charge. These positive and negative conventions are purely arbitrary, but much of science is based upon them. It is an observed fact that a *force* of repulsion acts between like charges and a force of attraction acts between unlike charges: the region in which these forces act is called an *electric field*. Electric charges are also acted upon by forces when they move in a *magnetic field* that possesses a component at right angles to their direction of motion. The size of an electric charge is measured in the derived *SI unit*, the *coulomb*. Symbol *Q*.

electric constant Permittivity of free space, ϵ_0 . The fundamental constant that has the value $8.854\ 16 \times 10^{-12}$ farad per metre. It arises as the constant of proportionality in *Coulomb's law*, its value depending on the choice of units. See also *electric field*; *permittivity*.

electric current An electric current is said to flow through a *conductor* when there is an overall movement of *electrons* through it. The *SI unit* of current is the *ampere*. Symbol *I*.

electric current, heating effect of When an *electric current* flows through a *conductor* of finite *resistance*, *heat energy* is continuously generated at the expense of *electrical energy*. The quantity of heat produced is proportional to the resistance of the conductor, and is equal to VI or I^2R watts (*joules per second*), *V* being the *potential difference* in volts, *I* the current in *amperes*, and *R* the resistance in *ohms*.

electric displacement Consider a uniform *electric field* of strength *E* in free space; i.e. the electric *flux* through unit area perpendicular to the field is *E*. Now suppose a *dielectric* medium is introduced into the field. The electric flux at any point in the medium becomes modified owing to the interaction between *E* and the *atoms* of the dielectric, and assumes a new value *D*, called the electric displacement.

electric field The region surrounding an *electric charge*, in which a *force* is exerted on a charged particle; completely defined in magnitude and direction at any point by the force upon unit positive charge situated at that point. The field strength *E*, or *force* exerted upon a unit charge at a distance *r* from a charge *Q*, is given by:

$$E = Q/4\pi r^2\epsilon$$

where ϵ is the *permittivity*. For free space (i.e. a vacuum) ϵ becomes ϵ_0 , the *electric constant*, and has the value $8.854\,185 \times 10^{-12} \text{ F m}^{-1}$.

electric flux The quantity of electricity displaced across unit area of a dielectric. It is the scalar product of the *electric displacement* and the area.

electricity A general term used for all phenomena caused by *electric charge* whether static or in motion.

electricity, frictional Triboelectricity. A separation of *electric charge* that results from the rubbing together of different materials; e.g. on rubbing *celluloid* with rabbit's fur, the fur is found to possess a positive charge, and the celluloid receives an equal negative charge. The rubbing motion strips some of the *electrons* from the *atoms* or *molecules* of the fur, which collect on the surface of the celluloid.

electricity, static *Electricity* at rest, in contradistinction to dynamic or current electricity. In the static case its effects are due purely to the *electrostatic field* produced by the charge, whereas in the case of current electricity other effects, in particular a *magnetic field*, are added.

electric light Illumination produced by the use of *electricity*; it may be produced by virtue of the heating effect of an *electric current* on a wire or *filament* (see *electric-light bulb*), by an electric arc (see *arc lamp*), or by the passage of electricity through a *vapour*, as in the *mercury vapour lamp* or *fluorescent lamps*.

electric-light bulb A glass bulb, often filled with nitrogen or some other chemically inactive *gas*, containing a wire or *filament*, usually made of tungsten. The passage of an *electric current* through the filament heats it to a white heat.

electric motor A device for converting *electrical energy* into *mechanical energy*, depending on the fact that when an *electric current* flows through a *conductor* placed in a *magnetic field* possessing a component at right angles to the conductor, a mechanical *force* acts upon the conductor. In its simplest form, it consists of a coil or *armature* through which the current flows, placed between the poles of a powerful *electromagnet*, the *field magnet*; the mechanical force upon the conductor causes the armature to rotate.

electric polarization *P*. When an *electric field* is applied to an electrically neutral *atom*, a displacement of the *electrons* with respect to the positive *nucleus* occurs. (See *atom, structure of*.) This gives rise to a small electric *dipole* possessing an electric *moment* in the direction of the field. This effect occurs when a *dielectric* is placed in an electric field, the electric field acting upon each individual atom of the dielectric. The electric polarization is given by

$$P = D - E\epsilon_0$$

where D is the *electric displacement*, E is the *electric field strength*, and ϵ_0 is the *electric constant*.

electric power The rate of doing work, measured in *watts*. A power of 1 watt does 1 *joule* of work per second. The power in watts is given by the product of the *potential difference* in volts and the *current* in amperes.

electric spark A discharge of *electricity*, accompanied by *light* and *sound*, through a *dielectric* or *insulator*.

electric susceptibility X_e . The ratio of the *electric polarization* (P) produced in a substance to the product of the *electric field strength* (E) to which it is subjected and the *electric constant* (ϵ_0), i.e.

$$X_e = P/E\epsilon_0$$

The susceptibility is related to the relative *permittivity* (ϵ_r) by

$$X_e = 1 - \epsilon_r.$$

electrocardiograph ECG. An instrument for recording the *current* and *voltage* waveforms associated with the contraction of the heart muscle.

electrochemical equivalent of an ion. The mass of the *ion* liberated or deposited by 1 *coulomb* of *electricity*. Expressed in grams, this is numerically equal to 1/96487 of the *chemical equivalent*, which is therefore liberated or deposited by 96487 coulombs, or one *faraday*. See *electrolysis*.

electrochemical series See *electromotive series*.

electrochemistry The study of the processes involved in the inter-conversion of *electrical energy* and *chemical energy*.

electrode 1. A *conductor* by which an *electric current* enters or leaves an *electrolyte* in *electrolysis*, an *electric arc*, or a vacuum tube (see *discharge in gases* and *thermionic valve*): the positive electrode is the *anode*, the negative one the *cathode*. 2. In a *semiconductor* device, an element that emits or collects *electrons* or *holes*, or controls their movement by an *electric field*.

electrodeposition The process of depositing by *electrolysis*, especially the deposition of one *metal* on another as in *electroplating*.

electrode potential The *electric potential* developed on an electrode that is in equilibrium with a solution of its *ions* (see also *half cell*). Electrode potentials cannot be measured absolutely and are usually specified by comparison with a *hydrogen electrode*, which is assumed to have an electrode potential of zero. In practice a number of more convenient electrodes are used, of known standard electrode potential. These are calibrated against the standard hydrogen electrode. See *calomel electrode*.

ELECTRODYNAMICS

electrodynamics The study of the relationship between electric and magnetic forces and their mechanical causes and effects.

electrodynamometer An instrument for measuring current, voltage, or power, in both *direct current* and *alternating current* circuits. It depends upon the interaction of the *magnetic fields* of fixed and movable coils.

electroencephalograph EEG. An instrument used for recording the rhythmical *electric currents* that pass through the brain. The pattern obtained can be correlated with certain human physiological states (e.g. sleep) and pathological states (e.g. epilepsy).

electroforming The production, or reproduction, of *metal* articles by the deposition of a metal upon an *electrode* during *electrolysis*.

electrokinetic potential Zeta-potential, ζ -potential. The *potential difference* across the *interface* between a moving liquid and the fixed liquid layer attached to the solid surface over which the liquid moves.

electrokinetics The study of *electric charges* in motion and their behaviour in *electric* and *magnetic fields*, as opposed to *electrostatics*.

electroluminescence *Fluorescence* resulting from bombardment of a substance with *electrons*.

electrolysis The chemical *decomposition* of certain substances (*electrolytes*) by an *electric current* passed through the substance in a dissolved or molten state. Such substances are ionized (see *ionic hypothesis*) into electrically charged *ions*, and when an electric current is passed through them by means of conducting *electrodes*, the ions move towards the oppositely charged electrodes, there give up their electric charges, become uncharged *atoms* or groups, and are either liberated or deposited at the electrode, or react chemically with the electrode, the *solvent*, or each other, according to their chemical nature.

electrolysis, Faraday's laws of 1. The chemical action of a current of *electricity* is proportional to the quantity of electricity that passes. 2. The masses of substances liberated or deposited by the same quantity of electricity are proportional to their *chemical equivalents*. See *electrochemical equivalent*. Named after Michael Faraday (1791-1867).

electrolyte A *compound* that, in *solution* or in the molten state, conducts an *electric current* and is simultaneously decomposed by it. The current is carried not by *electrons* as in *metals*, but by *ions* (see *electrolysis*). Electrolytes may be *acids*, *bases*, or *salts*.

electrolytic capacitor (condenser) A fixed electrical *capacitor* in which one *electrode* is a *metal* (usually aluminium) foil coated with a thin layer of the metal *oxide*, and the other electrode is a non-corrosive *salt solution* or paste. The metal foil is maintained positive to prevent the removal of the oxide film by the hydrogen liberated.

Tantalum sheets are also used as electrodes, immersed in an *electrolyte* of *sulphuric acid*. The advantage of electrolytic capacitors is that they provide a high *capacitance* in a limited space.

electrolytic dissociation, theory of An explanation of the phenomena of *electrolysis* on the supposition that *molecules of electrolytes* are partially or completely dissociated in solution into electrically charged *ions*. The degree of dissociation determines the electrical *conductivity* of the solution and also other properties, which can be related theoretically to the total number of molecules and ions of the electrolyte formed in the solution. Many compounds, e.g. *acetic acid*, have low degrees of dissociation and are called weak electrolytes. Others have high degrees of dissociation (strong electrolytes). Determinations by methods based on the classical theory of Arrhenius indicate that such electrolytes are not completely dissociated, but results by different methods of this type are quantitatively inconsistent. The modern theory, originated by Debye and Hückel, regards strong electrolytes as being completely dissociated and explains the experimental results by the occurrence of electrical interactions between the ions.

electrolytic gas Detonating gas. A mixture of hydrogen and oxygen, in a ratio of 2 to 1 by *volume*, formed by the *electrolysis* of *water*.

electrolytic rectifier. A *rectifier* consisting of two *electrodes* immersed in an *electrolyte*, which is used to convert an *alternating current* into a *direct current*. It depends on the properties of certain *metals* and *solutions* to allow current to flow in one direction only.

electrolytic separation A method of separating *deuterium* from *hydrogen*. When water is electrolyzed the hydrogen ion is discharged at the cathode slightly faster than the heavier isotope, deuterium. Thus, over a period, the water becomes enriched with deuterium.

electromagnet A temporary *magnet* formed by winding a coil of wire round a piece of soft iron; when an *electric current* flows through the wire, the iron becomes a magnet.

electromagnetic induction See *induction, electromagnetic*.

electromagnetic interaction The form of *interaction* that occurs between electrically charged *elementary particles*. It can be explained by the exchange of virtual *photons* (see *virtual state*) between the interacting particles.

electromagnetic moment See *magnetic moment*.

electromagnetic pump A device used for pumping *liquid metals*. A current is passed through the liquid metal, which is contained in a flattened pipe placed between the poles of an *electromagnet*. The liquid metal is thus subjected to a *force* which acts along the axis of the pipe.

electromagnetic radiation *Radiation* consisting of waves of *energy* associated with *electric* and *magnetic fields*, resulting from the acceleration of an *electric charge*. These electric and magnetic

ELECTROMAGNETIC SPECTRUM

fields, which require no supporting medium and can be propagated through space, are at right angles to each other and to the direction of propagation. Electromagnetic waves travel through space with a uniform velocity of 2.9979×10^8 metres per second, or 186 282 miles per second. The nature of electromagnetic radiations depends upon their frequency (see *electromagnetic spectrum*). Electromagnetic radiation is emitted by matter in discontinuous units called *photons*.

electromagnetic spectrum The range of frequencies over which electromagnetic radiations are propagated. The lowest frequencies are radio waves, increases of frequency produce *infrared radiation*, *light*, *ultraviolet radiation*, *X-rays*, and *gamma-rays*. See Appendix, Table 10.

electromagnetic units E.M.U. A system of electrical units, within the c.g.s. system, based on the unit magnetic pole, which repels a similar pole, placed 1 cm away, with a force of 1 dyne. The E.M.U. of electric current is that current that, flowing in an arc of a circle of unit length and radius (i.e. 1 cm), exerts a force of 1 dyne on a unit magnetic pole placed at the centre. The E.M.U. of resistance is that resistance in which energy is dissipated at the rate of 1 erg per second by the flow of 1 E.M.U. of current. The E.M.U. of electromotive force or potential is the potential that, applied across the ends of a conductor of 1 E.M.U. resistance, causes 1 E.M.U. of current to flow.

electromagnetic waves See *electromagnetic radiation* and *electromagnetic spectrum*.

electrometallurgy The study of electrical processes used in separating a metal from its ore; or refining or shaping metals by electrical means.

electrometer An instrument for measuring voltage differences, which draws no current from the source. Essential for measuring electrostatic voltage differences.

electromotive force E.M.F. The source of electrical energy required to produce an electric current in a circuit. It is defined as the rate at which electrical energy is drawn from the source and dissipated in a circuit when unit current is flowing in the circuit. The SI unit is the volt. See *potential difference*.

electromotive series Electrochemical series. Potential series of the metals. A list of metals arranged in order of the magnitudes of their molar electrode potentials, i.e. the potential difference between the metal and a normal solution of one of its salts. Metals with high negative electrode potentials stand at the head of the electromotive series. The list represents the order in which the metals replace one another from their salts, a metal higher in the series replacing one lower down; similarly, metals placed above hydrogen will liberate it from acids. The chief metals in order are sodium, magnesium,

aluminium, manganese, zinc, cadmium, iron, cobalt, nickel, tin, lead, hydrogen, copper, mercury, silver, platinum, gold.

electron An *elementary particle* having a rest mass of $9.109\,558 \times 10^{-31}$ kilogram, approximately $1/1836$ that of a hydrogen atom, and bearing a negative *electric charge* of $1.602\,192 \times 10^{-19}$ coulomb. The radius of the electron is $2.817\,77 \times 10^{-15}$ metre. The electron is a constituent of all atoms (see *atom*, *structure of*). The positively charged *anti-particle* of the electron is the *positron*, and the word 'electron' is sometimes used to include both negative electrons (negatrons or negatons) and positive electrons (positrons or positons). A *free electron* is one that has been detached from its atomic orbit.

electron affinity In general, the tendency of an atom or molecule to accept an *electron* and form a negative *ion*. In particular, the energy liberated when one mole of an *element* in the form of gaseous atoms is converted into negative ions. The *halogens* have high electron affinities.

electron capture 1. The formation of a negative *ion* when a *free electron* is captured by an atom or molecule (also referred to as 'electron attachment'). 2. A *radioactive transformation* as a result of which a *nucleus* captures one of its orbital electrons.

electron density The density of *electronic charge* at a given point in a molecule; alternatively defined as the probability of finding an *electron* at the particular point.

electron diffraction A *diffraction* effect resulting from the passage of electrons through matter, analogous to the *diffraction* of visible light or X-rays. The phenomenon of electron diffraction is the principal evidence for the existence of waves associated with electrons (see *de Broglie wavelength*). The diffraction of electrons when passed through *crystals* or thin *metal* foils is used as a method of investigating crystal structure.

electronegative elements and groups. *Radicals* that behave as negative ions; radicals taking up *electrons*, thus acquiring a negative *electric charge*, when united with other radicals by electrovalent bonds (see *valence*, *electronic theory of*). The *halogens*, oxygen, sulphur, and other *non-metallic elements* are generally electronegative.

electronegativity The tendency of an atom to attract *electrons*. See *valence*, *electronic theory of*.

electron exchanger See *redox exchanger*.

electron gun The source of *electrons* in a *cathode ray tube* or *electron microscope*. It consists of a *cathode* emitter of electrons, an *anode* with an aperture through which the beam of electrons can pass, and one or more focusing and control *electrodes*.

electronic charge The negative *electric charge* of the *electron*, 1.6021×10^{-19} coulomb, $4.802\,98 \times 10^{-10}$ electrostatic unit.

ELECTRONICS

electronics An applied physical science concerned with the development of electrical circuits using *semiconductors*, *thermionic valves*, and other devices in which the motion of *electrons* is controlled.

electron lens A system of *electric* or *magnetic fields* used to focus a beam of *electrons* in a manner analogous to an optical *lens*. Used in *electron microscopes*, etc.

electron micrograph A photograph of an object obtained with an *electron microscope*.

electron microscope An instrument similar in purpose to the ordinary *light microscope*, but with a much greater *resolving power*. Instead of a beam of light to illuminate the object, a parallel beam of *electrons* from an *electron gun* is used. In the transmission electron microscope, the object, which must be in the form of a very thin film of the material, allows the electron beam to pass through it; but, owing to differential *scattering* in the film, an image of the object is carried forward in the electron beam. The latter then passes through a magnetic or *electrostatic* focusing system (see *electron lens*) which is equivalent to the optical lens system in an ordinary microscope, i.e. it produces a much magnified image. This is received on a fluorescent screen and recorded by a camera. Magnifications up to 200 000 can be achieved. In the scanning electron microscope a thick sample can be used and the sample is scanned by the electron beam. Secondary electrons emitted from the surface of the sample are focused into a screen. The magnification is less with this type of instrument, but a three-dimensional image is formed.

electron multiplier See *photomultiplier*.

electron probe microanalysis A method of analysing a very small quantity of a substance by directing a finely focused *electron* beam on to it so that an *X-ray* emission is produced characteristic of the *elements* present in the sample. The diameter of the beam is usually about 1 μm and quantities as small as 10^{-13} g can be detected by this means. The method may be used quantitatively for elements whose *atomic numbers* exceed 11.

electron spin resonance A phenomenon exhibited by paramagnetic substances (see *paramagnetism*) due to their unpaired *electrons*. The *spin* of an unpaired electron is associated with a *magnetic moment* that may align itself in one of two ways with respect to an applied *magnetic field*, each possible alignment corresponding to a different *energy level*. By applying an alternating magnetic field at right angles to the first unvarying magnetic field transitions between these two energy levels can be made, falling in the *microwave* region of the *electromagnetic spectrum*, thus producing the phenomenon known as electron spin resonance. If, however, the paramagnetic *molecule* includes magnetic nuclei, these transitions will interact with the nuclear spin (see *nuclear magnetic resonance*)

producing a series of lines rather than a single resonance. Electron spin resonance spectroscopy consists of analysing this *hyperfine structure* so that the electron can be located within the molecule, thus providing information about the molecule's structure.

electron-volt eV. A unit of *energy* widely used in *nuclear physics*. The increase in energy or the *work* done on an *electron* when passing through a *potential* rise of 1 *volt*. 1 electron-volt = 1.602×10^{-19} *joule*. 1 MeV = 10^6 electron-volts; 1 GeV = 10^9 electron-volts.

electrophilic reagents Cationoid reagents. *Reagents* that react at centres of high *electron density*. Essentially electron acceptors (e.g. *halogens*) that gain or share electrons from an outside *atom* or *ion*.

electrophoresis Cataphoresis. The migration of the electrically charged *solute* particles present in a *colloidal solution* towards the oppositely charged *electrode*, when two electrodes are placed in the solution and connected externally to a source of *E.M.F.*

electrophorus A laboratory demonstration apparatus for showing electrostatic charging by *induction*.

electroplating Depositing a layer of *metal* by *electrolysis*, the object to be plated forming the *cathode* in an electrolytic tank or bath containing a *solution* of a *salt* of the metal that is to be deposited.

electropositive elements and groups. *Radicals* that behave as positive *ions*; radicals that give up *electrons*, thus acquiring a positive *electric charge*, when united with other radicals by electrovalent bonds (see *valence, electronic theory of*). The *metals* and *acidic hydrogen* are generally electropositive.

electroscope An instrument for detecting the presence of an *electric charge*. The gold-leaf electroscope consists of two rectangular leaves of gold foil attached to a conducting rod of *metal* held by an insulating plug; when the rod and leaves acquire an electric charge, the leaves diverge owing to the mutual repulsion of charges of like sign.

electrostatic field A region in which a stationary electrically charged particle would be subjected to a *force* of attraction or repulsion as a result of the presence of another stationary *electric charge*. See *electric field*.

electrostatic generator A machine designed for the continuous separation of *electric charge*. Examples include the *Wimshurst machine* and the *Van de Graaff generator*.

electrostatic precipitation A widely used method of controlling the pollution of air (or other gases). The gas, containing *solid* or *liquid* particles suspended in it, is subjected to a uni-directional *electrostatic field*, so that the particles are attracted to, and deposited upon, the positive *electrode*. See *Cottrell precipitator*.

electrostatics The study of static *electricity*.

ELECTROSTATIC UNITS

electrostatic units ESU. A system of electrical *units* based upon the electrostatic unit of *electric charge*. The electrostatic unit of charge (called the *statcoulomb*) is that quantity of electricity that will repel an equal quantity, 1 cm distant from it in a *vacuum*, with a force of 1 *dyne*.

electrostriction The change in the dimensions of a *dielectric* when placed in an electric *field*. An example is the contraction of a *solvent* due to the *electrostatic field* of a dissolved *electrolyte*.

electrotyping The production of copies of plates of type, etc., by the electrolytic deposition of a layer of *metal* on a previously prepared mould. This is a cast of the object to be copied, made of *plastic* material and coated with a layer of *graphite*, which acts as a *conductor* of electricity. It is then suspended to act as a *cathode* in an electrolytic bath (see *electroplating*) containing a *solution* of a *salt* of the metal required, usually copper. The passage of an *electric current* will deposit a layer of any required thickness of metal upon the cathode, the layer being a replica of the original type.

electrovalence See *valence, electronic theory of*.

electrovalent crystal Ionic crystal. The type of *crystal* in which the component *ions* are held in their positions in the *lattice* by electrovalent bonds (see *valence, electronic theory of*). *Sodium chloride* is a typical example.

electrum A natural *alloy* of gold (55%-85%) and silver.

element (chem.) A substance consisting entirely of *atoms* of the same *atomic number*. The elements are listed in the Appendix, Table 3.

elementary particles Fundamental particles. The basic units of which all *matter* is composed. The stable particles *protons*, *electrons*, and *neutrinos* combine with *neutrons* to form stable *atoms*. But many other short-lived particles and *resonances* have been detected that play an essential part in the structure of matter. For every particle that exists there is a corresponding *anti-particle*, which has the same *mass* and *spin* but opposite *electric charge*. Some electrically *neutral* particles have anti-particles in which some other property is reversed (e.g. *strangeness*) and some neutral particles are regarded as their own anti-particles. There are several systems for classifying particles: one way is to divide them into *fermions* (with spin quantum number $\frac{1}{2}$) and *bosons* (with integral spin quantum number). Fermions are sub-divided into *baryons* and *leptons*, while bosons are sub-divided into *mesons* and *photons*. Another way of classifying particles is based on the way in which they interact. Particles that take part in *strong interactions*, the baryons and mesons, are known as *hadrons*, while those taking part in *weak interactions* are the leptons. In some circumstances hadrons also take part in weak interactions, but leptons are insensitive to the strong interactions. The *quark* model is based on this kind of classification. In the quark model the only truly elementary particles

are quarks (and antiquarks) and leptons. In this theory all hadrons are made up of quarks, mesons of a quark and antiquark and baryons of three quarks. However, the concept of elementarity is still somewhat vague as no quarks have actually been detected. See also *charm*; *strangeness*. Some of the most important particles are listed in Table 6 of the Appendix.

elements (astr.) The numerical values required to define the elliptical orbit of a *planet* or *satellite*, such as the semi-major axis of the *ellipse*, and its *eccentricity*. The *plane* of the orbit is defined by the angle its plane makes with the *planet* of the *ecliptic*.

elements, magnetic See *magnetic elements*.

elevation, angle of If *C* is a point above the level of another point *A*, the angle of elevation of *C* from *A* is the *angle* that *C* makes with the horizontal plane *AX* through *A*. See Fig. 11 under *depression*, *angle of*.

elevation of boiling point The rise in the *boiling point* of a *solution* produced by a non-volatile substance dissolved in a *solvent*. For a *dilute* solution the elevation is proportional to the number of *molecules* or *ions* present (see *colligative properties*), and the elevation produced by the same *molecular concentration* (or ionic concentration in the case of an *electrolyte*) is a constant for a particular solvent. This forms the principle of the boiling point method (ebulliscopic method) for the determination of *molecular weights*.

eleven-year period A periodic change in occurrence of *sunspots*, the cycle being complete in approximately eleven years; associated with this is a cyclic variation in the magnitude of the *daily variation*.

Elinvar* A variety of *steel* containing 36% nickel and 12% chromium. The *elasticity* is almost unaffected by changes of *temperature*; used for hair-springs of watches.

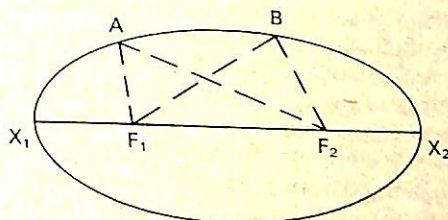


Figure 15.

ellipse A closed *plane* figure formed by cutting a right circular *cone* by a *plane* obliquely through its *axis* (see *conic sections*). The sum of the distances from any point on the *perimeter* of an ellipse to its two *foci* is constant. In Fig. 15, X_1X_2 is the *major axis*, F_1 and F_2 are

ELLIPSOID

the foci, and A and B are any points on the perimeter such that $AF_1 + AF_2 = BF_1 + BF_2$.

ellipsoid A solid figure traced out by an *ellipse* rotating about one of its axes.

elliptically polarized light Light that can be resolved into two vibrations lying in *planes* at right angles, and of equal *frequency*. The electric vector at any point in the path of the wave describes an *ellipse* about the direction of propagation of the light. The form of this ellipse is determined by the *amplitudes* of these two vibrations and by the difference of *phase* between them. (See also *polarization of light*.)

elution The removal of an *adsorbate* from an adsorbent by dissolving it in a *liquid* (the eluent). The resulting solution is called the eluate.

elutriation The washing, separation, or sizing of fine particles of different *weight* by suspending them in a current of air or water.

emanation Radium emanation. The gas formed by the *radioactive disintegration* of certain substances, consisting principally of radon, thoron, and actinon.

embryology The branch of *biology* concerned with the study of the growth and development of embryos.

emery A mixture of *corundum* and iron oxide, usually *magnetite*, Fe_3O_4 . Used as an *abrasive*.

emetine $C_{29}H_{40}O_4N_2$. An *alkaloid* obtained from the roots of Brazilian *ipecacuanha*, m.p. $68^\circ C$. Used as an emetic and as a remedy for amoebic dysentery.

E.M.F. See *electromotive force*.

emission of radiation The net rate at which a body emits *heat radiation* to its surroundings depends on the *temperature* of the body, the temperature of its surroundings, and the nature of the surface of the body. Dull black surfaces have the greatest *emissive power* while brightly polished reflecting surfaces have least. See *Stefan's law*.

emission spectrum The *spectrum* observed when electromagnetic radiation coming directly from a source is examined with a *spectroscope*. The source must be heated or bombarded with particles in order to excite the atoms and molecules of which it consists. The emission occurs when these excited atoms or molecules decay to a lower energy state. See also *absorption spectrum*.

emissive power, total. The total *energy* emitted from unit area of a surface of a body per second. The total emissive power depends upon the *temperature* of the body and the nature of its surface.

emissivity The ratio of the total *emissive power* of a body to the total emissive power of a perfect black body at the same *temperature* (see *black body radiation*). The emissivity is a pure numeric, equal to the *absorptivity*. Symbol ϵ .

emitter One of the three *electrodes* in a *transistor*.

empirical Based upon the results of experiment and observation only.

empirical formula The simplest type of chemical *formula*, giving only the proportion of each *element* present, but no indication of the *molecular weight* or the molecular structure, e.g. $(C_4H_3O_2N)_n$.

emulsifying agent A substance, small quantities of which help to form or stabilize an *emulsion*.

emulsion A two-phase system in which the *disperse phase* consists of minute droplets of *liquid*.

emulsion, photographic The light-sensitive coating on a *film* or plate (see *photography*). A 'nuclear emulsion' is a photographic emulsion specially prepared to record the tracks of *elementary particles* and nuclear fragments that pass through it.

emulsoid sol See *colloidal solutions*.

enamel 1. A class of substances (vitreous enamels) having similar composition to *glass* with the addition of *stannic oxide*, SnO_2 , or other *infusible* substances to render the enamel *opaque*. 2. A finely ground oil *paint* containing a *resin*. 3. The external layer of teeth consisting mainly of calcium phosphate carbonate *salts*.

enantiomorphism The occurrence of substances in two crystalline forms, one being a mirror image of the other. See also *optical isomerism*.

enantiotropic substances. Substances that exist in two different physical forms, one being *stable* below a certain *temperature* (the *transition temperature*), the other above it. E.g. sulphur exists as alpha-sulphur at all temperatures below $96^\circ C$.; above this, the stable form is beta-sulphur.

endocrine glands See *ductless glands*.

endoenzyme An *enzyme* that remains within a living *cell* and does not diffuse through the cell wall into the surrounding medium.

endoergic process An *endothermic process* (often applied in the context of a *nuclear reaction*).

endoplasm The central part of the *cytoplasm* of living *cells*, usually distinct from the *ectoplasm* in that it is of greater fluidity and contains more granules.

endoplasmic reticulum A system of membranes within the *cytoplasm* of many types of living *cell*. It appears to be connected with *protein* synthesis as these membranes are often covered with *ribosomes* in cells that make large quantities of protein.

endosmosis The inward flow of *water* into a cell containing an *aqueous solution*, through a *semipermeable membrane*, due to *osmosis*.

endothermic process A process accompanied by the absorption of *heat*.

end point The point in a *titration*, usually indicated by a change of colour of an *indicator*, at which a particular *reaction* is completed.

energy The capacity for doing *work*. The various forms of energy, interconvertible by suitable means, include *potential*, *kinetic*, *electrical*, *heat*, *chemical*, *nuclear*, and *radiant energy*. Inter-

ENERGY BANDS

conversion between these forms of energy can only occur in the presence of *matter*. Energy can only exist in the absence of matter in the form of radiant energy. The derived *SI unit* of energy is the *joule*. Symbol *E*.

energy bands *Orbital electrons* are associated with specific amounts of energy, the change from one *energy level* to another taking place in *quantized* steps. In a crystalline *solid* the energies of all the electrons and *atoms* fall into several 'allowed' energy bands between which lie 'forbidden' bands. These bands may be depicted on an 'energy level diagram'. The range of energies corresponding to states in which the electrons can be made to flow, by an applied *electric field*, is called the *conduction band*. The range of energies corresponding to states that can be occupied by *valence electrons*, binding the *crystal* together, is called the *valence band*. The valence band in an ideal crystal is completely occupied at the *absolute zero* of temperature, but in real crystals above absolute zero some electrons are missing from the valence band, and it is these electrons that give rise to *holes*.

energy flux The rate of flow of energy per unit area. See *flux*.

energy levels An *atom* as a whole, or an individual *nucleus*, can exist only in certain definite states characterized by the *energy* of the state. Thus, for each different atom or nucleus, there exists a series of energy levels corresponding to these permissible states. The lowest stable energy level of an atom or nucleus is referred to as the *ground state*; atoms or nuclei at higher energy levels than the ground state are said to be excited. See *excitation*.

energy-rich bonds A term used in *biochemistry* to distinguish between chemical *bonds* that when broken yield a large amount of *free energy* and those that give only a small yield of free energy ('energy-poor bonds'). The energy referred to in this context is the free energy liberated on *hydrolysis*. Energy-rich bonds usually involve *phosphate* groups and in this respect *adenosine triphosphate* (*ATP*) is of particular significance.

energy value of a food. A measure of the *heat* energy available by the complete combustion of a stated *weight* of the food; often given in joules per kilogram or large *Calories* per lb. It takes no account of the value of the food from any other point of view, or sometimes even of the suitability of the food for use by the human *organism*.

engine A device for converting one form of *energy* into another, especially for converting other forms of energy into *mechanical* (i.e. *kinetic*) energy.

enrich In general, to increase the *abundance* of a particular *isotope* in a mixture of isotopes. In particular, to increase the abundance of the *fissile* isotope of a *nuclear fuel*.

enthalpy Heat Content. *H*. A *thermodynamic* property of a substance

given by $H = U + pV$, where U is the internal energy, p the pressure, and V the volume.

entrainment The transport of particles (e.g. fine droplets) in a moving stream of a fluid (e.g. the vapour of a boiling liquid).

entropy S . A quantity introduced in the first place to facilitate the calculations, and to give clear expression to the results of *thermodynamics*. Changes of entropy (ΔS) can be calculated only for a *reversible process*, and may then be defined as the ratio of the amount of heat taken up (ΔQ) to the *absolute temperature* (T) at which the heat is absorbed, i.e. $\Delta S = \Delta Q/T$. Entropy changes for actual irreversible processes are calculated by postulating equivalent theoretical reversible changes. The entropy of a system is a measure of its degree of disorder. The total entropy of any isolated system can never decrease in any change; it must either increase (irreversible process) or remain constant (reversible process). The total entropy of the *Universe* therefore is increasing, tending towards a maximum, corresponding to complete disorder of the particles in it (assuming that it may be regarded as an isolated system). See *heat death of the Universe*.

enyne A hydrocarbon with a double (-ene) and a triple (-yne) bond between carbon atoms in its molecule.

enzyme A large group of *proteins* produced by living cells, which act as *catalysts* in the *chemical reactions* upon which life depends. The exact mechanism by which enzymes act is not fully understood; but it appears that certain parts of the enzyme molecule (called the 'active centres') combine with the substrate molecule in such a way that the substrate undergoes chemical changes very much more rapidly than it would in the absence of the enzyme, while the enzyme itself remains unchanged. As enzymes are not consumed in these reactions they are effective in only minute quantities. Nearly all enzymes are highly specific in their action and therefore enormous numbers of them are found in nature. Many enzymes require the assistance of certain accessory substances (e.g. *co-enzymes*) for their proper functioning and some require precisely defined conditions of *temperature* and *pH* for their optimum performance.

Enzymes are usually named by adding the suffix -ase to a word indicating the nature of the substrate (e.g. *amylase*) or the type of reaction involved (e.g. *dehydrogenase*). A few enzymes retain old names that relate to neither of these rules (e.g. *pepsin*, *trypsin*).

enzymolysis The *decomposition* of a substance catalyzed by an enzyme.

eosin Tetrabromofluorescein. $C_{20}H_8Br_4O_5$. A red crystalline *insoluble* substance obtained from *fluorescein*, m.p. 295-6°C., used as a red dye.

epact 1. The difference in days between the length of a solar year and a lunar year. **2.** The *Moon's* age in days at the start of the calendar year.

ephedrine $C_6H_5CHOHCH(CH_3)NHCH_3$. A white crystalline *optically active alkaloid*, m.p. $40^\circ C.$, used in medicine to treat asthma, colds, etc.

ephemeris A table that gives the predicted positions and the movements of a celestial body such as a *planet* or *comet*. Also an annual publication containing astronomical data.

ephemeris time Time measured on the basis of the orbital movements of the *planets* and the *Moon*.

epicentre The point on the surface of the Earth that lies directly above the focus of an earthquake.

epichlorohydrin 1-Chloro-2,3-epoxypropane. $\overline{OCH_2CHCH_2Cl}$. A colourless liquid, b.p. $116^\circ C.$ A highly reactive *epoxy* compound used in the manufacture of *epoxy resins* and in many other reactions of organic synthesis.

epicycle 1. (math.) a *circle* whose centre rolls round the circumference of a larger circle without slipping. **2.** (astr.) Ptolemy (A.D. 90-168) based his *astronomy* on the theory that the *planets* moved in epicycles round a larger circle, called the deferent, at the centre of which lay the *Earth*.

epicyclic gears A system of gears in which one or more wheels move around the outside, or the inside, of another wheel whose axis is fixed.

epidiascope An optical projector for throwing an enlarged image of either an *opaque* object or a transparency upon a screen. Used for illustrating lectures.

epimerism A type of *optical isomerism* occurring in *carbohydrates* and some other types of compound. It is due to the formation of isomers (epimers) that differ in their molecular arrangements about an asymmetric atom in a molecule containing two or more asymmetric atoms.

epinephrine See *adrenaline*.

epitaxy The growth of one crystalline substance on another so that both have the same crystal structure. Epitaxial layers are used in the manufacture of semiconductor devices.

epithermal neutrons Neutrons that have *energies* in excess of the energy associated with thermal agitation. Neutrons that have speeds and energies intermediate between *fast* and *thermal neutrons* (i.e. between about 0.1 and 100 *electron-volts*).

epoxy A *compound* in which an oxygen atom is bound to two carbon atoms, forming a three-membered ring.

epoxy resins *Thermosetting resins* made by the reaction of *epichlorohydrin* with *polyhydric* compounds, such as bisphenol A (4,4'-isopro-

pylidenediphenol), in the presence of a *catalyst*. Used in manufacture of electrical components, as structural materials, in surface coatings, and as *adhesives*.

epsom salts See *magnesium sulphate*. $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.

equation, chemical A representation of a *chemical reaction*, using the *symbols* of the *elements* to represent the actual *atoms* and *molecules* taking part in the reaction; the re-arrangement of the various atoms of the substances taking part is thus shown. E.g. the chemical equation $\text{H}_2 + \text{Cl}_2 = 2\text{HCl}$ represents the reaction between hydrogen and chlorine to form *hydrogen chloride*, and states that a hydrogen molecule, consisting of two atoms of hydrogen (H_2), reacts with a similarly constituted chlorine molecule, to give two molecules of hydrogen chloride, each consisting of one hydrogen and one chlorine atom (2HCl). From a knowledge of the equation for any chemical reaction, and of the *atomic weights* of all the elements taking part, it is thus possible to calculate the proportions by *weight* in which the substances react, since the whole bulk of the reaction consists merely of the repetition, a vast number of times, of the process depicted by the equation.

equation, mathematical A statement of equality between known and unknown quantities. Thus the equation $3x = 15$ is true only when $x = 5$.

equation of state of a substance. Any equation connecting the *pressure* p , *volume* V , and *temperature* T of the substance. Some equations of state attempt to cover more than one *phase* of the substance, e.g. *Van der Waals' equation of state*, and are approximate. Others are intended to be applied to one particular phase of the substance, e.g. the gaseous phase, and then only within certain limits of p , V , and T . With these limitations, these latter equations can represent the actual behaviour of the substance with greater accuracy.

equation of time The difference between mean solar time, as given by a clock, and apparent solar time, i.e. sundial time. The time of rotation of the *Earth* upon its axis is not exactly equal to the time from noon to noon, the difference being caused by the motion of the *Earth* relative to the *Sun* to complete a circuit in one *year*, and also by the inclination of the *ecliptic* to the *Equator*.

equator, terrestrial The *great circle* of the *Earth*, lying in a *plane* perpendicular to the *axis* of the *Earth*, that is equidistant from the two Poles. See also *magnetic equator* and *celestial equator*.

equilateral figure A figure having all its sides equal in length. E.g. an *equilateral triangle*.

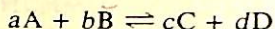
equilibrium A state of balance between opposing *forces* or effects.

equilibrium, chemical See *chemical equilibrium*.

equilibrium constant In any *chemical reaction* there is always a state of *chemical equilibrium*, at a given *temperature* and *pressure*, between the *concentration* of the reactants and the *concentration* of the

EQUIMOLECULAR MIXTURE

products. The position of this equilibrium, under specific conditions, is expressed by the equilibrium constant, K , such that in the reaction



K is given by:

$$(C_C)^c \cdot (C_D)^d / (C_A)^a \cdot (C_B)^b,$$

where C_A is the concentration of the substance A, 'a' molecules of which take part in the reaction.

equimolecular mixture A mixture containing substances in equal molecular proportions; i.e. in the ratio of their *molecular weights*. E.g. *invert sugar*, formed by the *hydrolysis* of *cane-sugar*. Each molecule of the cane-sugar is split into a molecule of *glucose* and a molecule of *fructose*, thus forming an equimolecular mixture of the two latter.

equinox The moment (or, astronomically, the point) at which the Sun apparently crosses the *celestial equator*; the point of intersection of the *ecliptic* and the celestial equator.

equipartition of energy In any physical system in thermal equilibrium the average *energy per degree of freedom* is the same, and equals $kT/2$, where k = Boltzmann's constant and T = the *absolute temperature* of the system. This provides a means of calculating the total thermal energy of a system. Thus, in 1 mole of a monatomic gas, each atom possesses three degrees of freedom (due to its *translatory motion*), and the total number of atoms is L (*Avogadro's constant*). Hence the total energy per mole of the gas is $3LkT/2$ or $3RT/2$, since $k = R/L$, where R is the *gas constant*.

equipotential lines and surfaces Lines and surfaces having the same *electric potential*.

equivalent, electrochemical See *electrochemical equivalent*.

equivalent weight See *chemical equivalents*.

equivocation A term used in *information theory* to indicate the rate of loss of information (per second or per symbol) at the receiving end of a *channel* of information due to *noise*.

erbium Er. Element. A.W. 167.26. At. No. 68. R.d. 9.164, m.p. 1497°C. See *lanthanides*.

erecting prism A right-angled optical *prism* used in optical instruments to render an inverted image upright.

erg A unit of work or energy in the *c.g.s. system* of units; the work done by a force of 1 dyne acting through a distance of 1 cm. 1 erg = 10^{-7} joule.

ergometrine Ergonovine. $C_{19}H_{23}N_3O_2$. A colourless crystalline *alkaloid*, obtained from ergot, and used in medicine to prevent haemorrhage.

- ergonomics** The engineering aspects of the study of the relation between human workers and their working environment.
- ergosterol** $C_{28}H_{43}OH$. A white crystalline *sterol*, m.p. $163^{\circ}C.$, that occurs in small amounts in the *fats* of animals; it is converted into *vitamin D₂* (*calciferol*) by the action of *ultraviolet radiation*.
- ergotamine** $C_{33}H_{35}N_5O_5$. A crystalline *insoluble polypeptide*, m.p. $212.4^{\circ}C.$, obtained from ergot, and used in the form of its *tartrate* in medicine as a uterine stimulant.
- ergotoxine** $C_{35}H_{41}N_5O_6$. A white crystalline *insoluble alkaloid*, obtained from ergot, and used in medicine as a uterine stimulant.
- Erinoid*** A *thermoplastic* material prepared from *casein* and *formaldehyde*.
- Erlenmeyer flask** A flat-bottomed conical laboratory flask with a narrow neck. Named after E. Erlenmeyer (1825-1909).
- erythritol** 1,2,3,4-Butanetetrol. $(CH_2OHCHOH)_2$. An *optically active* white crystalline *polyhydric alcohol*, m.p. $121.5^{\circ}C$. Used as an *intermediate* in organic synthesis. The tetranitrate ester is used in medicine for treatment of heart disease and high blood pressure.
- erythrocytes** Red blood cells. The cells of the *blood* that contain *haemoglobin* and whose function it is to transport oxygen through the body. Erythrocytes have no means of propulsion, and in mammals the cells have no *nuclei*. Human blood contains approximately five million erythrocytes per cubic millimetre.
- Erythromycin*** $C_{37}H_{67}NO_{13}$. An *antibiotic* produced by the *Actinomycete* mould, used to combat a variety of bacterial infections.
- escape velocity** The *velocity* that a projectile or *space probe* would need to attain in order to escape from a particular *gravitational field*. The escape velocity from the surface of a *planet* (or *moon*) depends on the planet's (or moon's) *mass* and diameter. The escape velocity from the *Earth's* surface is about 11 200 metres/s (25 000 m.p.h.) and from the *Moon's* surface about 2370 metres/s (5300 m.p.h.).
- essential oils** Natural *oils* obtained from plants, mostly *benzene derivatives* or *terpenes*. Used for their flavour or odour.
- esterases** *Enzymes* that control *hydrolysis* of *esters*.
- ester gums** Rosin esters. Products made by *esterification* of *organic acids* in *rosin* with *polyhydric alcohols*, especially *glycerol*. Used in varnishes.
- esterification** The formation of an *ester* by the *chemical reaction* of an *acid* with an *alcohol*; e.g. the action of *ethanol* on *acetic acid* to form *ethyl acetate* and *water*.
- esters** *Organic compounds* corresponding to *inorganic salts*, derived by replacing hydrogen of an *acid* by an *organic radical* or group. E.g. *ethyl acetate*, $CH_3COOC_2H_5$, is the *ethyl ester* of *acetic acid*, CH_3COOH . Many esters are pleasant-smelling *liquids* used for

ETALON

flavouring essences. Many vegetable and animal *fats and oils* also belong to this class.

etalon An *interferometer* used for studying fine *spectrum* lines. It depends upon the interference effects produced by multiple reflection between fixed, parallel, half-silvered *glass* or *quartz* plates.

ethanal See *acetaldehyde*.

ethanamide See *acetamide*.

ethane C_2H_6 . The second member of the *alkane* series. A colourless odourless gas. B.p. $-88^\circ C$. Used chiefly in organic synthesis.

ethanediol Ethylene glycol, glycol. $(CH_2OH)_2$. A colourless *viscous liquid* with a sweet taste, b.p. $197^\circ C$. Used as an *anti-freeze*, in the manufacture of *plasticizers*, and as a *solvent*.

ethanethiol Ethyl mercaptan. C_2H_5SH . A colourless inflammable *liquid*, b.p. $37^\circ C$., used in the manufacture of *rubber accelerators*.

ethanoic acid See *acetic acid*.

ethanoic anhydride See *acetic anhydride*.

ethanol Ethyl alcohol, spirits of wine. C_2H_5OH . A colourless inflammable *liquid*, b.p. $78.5^\circ C$. Prepared by the *fermentation* of *sugars*. The active constituent of alcoholic drinks; used as a *fuel* and in the manufacture of other *organic compounds*. See *proof spirit* and *absolute alcohol*.

ethanolamines Organic *amines* derived from *ethanol*: monoethanolamine, a colourless viscous liquid, $NH_2CH_2CH_2OH$, m.p. $10.3^\circ C$., b.p. $172^\circ C$.; diethanolamine, $NH(CH_2CH_2OH)_2$, a viscous liquid or *deliquescent* white solid, m.p. $28^\circ C$.; triethanolamine, $N(CH_2CH_2OH)_3$, a highly *hygroscopic* viscous colourless liquid, m.p. $21^\circ C$. They are manufactured by the action of *ammonia* on *ethylene oxide* and are used for the absorption of *acid gases*, and as *intermediates* in the production of *surfactants*.

ethene See *ethylene*.

ethenoid plastics A class of *thermoplastic resins* made from substances containing a *double bond*, e.g. *acrylic*, *styrene*, and *vinyl resins*.

ether (aether) The hypothetical medium that was supposed to fill all space: postulated as a medium to support the propagation of *electromagnetic radiations*. Once the subject of controversy, now regarded as an unnecessary assumption.

ethers A group of *organic compounds* with the general formula $R-O-R'$ formed by the *condensation* of two *alcohol molecules*. The compound commonly called 'ether' is diethyl ether, $C_2H_5.O.C_2H_5$, b.p. $34.6^\circ C$., made by dehydrating *ethanol* by means of concentrated *sulphuric acid*. Diethyl ether is used as an *anaesthetic* and as a *solvent*.

ethoxy The *univalent radical* C_2H_5O- .

ethyl acetate $CH_3COOC_2H_5$. A colourless *liquid* with a pleasant fruity smell, b.p. $77^\circ C$. Used as a *solvent* and in medicine.

ethyl alcohol See *ethanol*.

ethyl butyrate Butyric ether. $C_3H_7COOC_2H_5$. A *volatile liquid*, b.p. $120^\circ C.$, used in flavouring and in perfumes.

ethyl carbamate Urethan(e). $NH_2COOC_2H_5$. A white crystalline solid, m.p. $48^\circ C.$ Used in the molten state as a solvent; it is also used as an *intermediate* in the manufacture of resins and in medicine.

ethylene Ethene. $H_2C:CH_2$. The first member of the series of *hydrocarbons*. A colourless inflammable gas with a sweetish smell, b.p. $-103.9^\circ C.$, used as an *anaesthetic* and in the manufacture of *polythene*.

ethylenediaminetetraacetic acid See *EDTA*.

ethylene dibromide See *dibromoethane*.

ethylene dichloride See *dichloroethane*.

ethylene glycol See *ethanediol*.

ethylene oxide 1,2-Epoxyethylene, $\overbrace{CH_2CH_2O}$ A colourless inflammable toxic gas (liquid below $10.7^\circ C.$), made by the *oxidation* of *ethylene* in the presence of a catalyst. It is an important *intermediate* in the production of *ethanediol*, *ethanolamines*, *surfactants*, etc.

ethylene-propylene rubber EPR. A fully *saturated*, *stereo-regular*, *synthetic rubber* prepared by the solution *polymerization* of approximately equal proportions of *ethylene* and *propylene*. It cannot be cured by sulphur vulcanization but satisfactory vulcanization can be achieved by using peroxide curing systems.

ethyl fluid A *solution* of *tetraethyl lead*, $Pb(C_2H_5)_4$, and *dibromoethane*, $C_2H_4Br_2$, used as an *anti-knock* compound in motor fuel.

ethyl group The *univalent alkyl radical* $-C_2H_5$.

ethyl nitrite Nitrous ether. $C_2H_5NO_2$. A *volatile liquid* with a sweet smell, b.p. $17^\circ C.$, used in medicine.

ethyne See *acetylene*.

euchlorine A gaseous *mixture* of chlorine, Cl_2 , and explosive chlorine peroxide, ClO_2 .

eudiometer A glass tube for measuring volume changes in *chemical reactions* between gases.

eugenics The study of the genetic control of human populations, with a view to improving their constitution, by selectively encouraging breeding among those people considered by eugenicists to be the most desirable.

eugenol $C_{10}H_{12}O_2$. A colourless oily *liquid*, m.p. $9.2^\circ C.$, b.p. $255^\circ C.$, extracted from oil of cloves. Used in perfumes and as an *antiseptic*.

europium Eu. Element. A.W. 151.96. At. No. 63. R.d. 5.24, m.p. $826^\circ C.$ See *lanthanides*.

eutectic mixture A *solid solution* of two or more substances, having the lowest *freezing point* of all the possible mixtures of the components.

EUTECTIC POINT

This is taken advantage of in *alloys* of low *melting point*, which are generally eutectic mixtures.

eutectic point Two or more substances capable of forming *solid solutions* with each other have the property of lowering each other's *freezing point*; the minimum freezing point attainable, corresponding to the *eutectic mixture*, is termed the eutectic point.

evaporation The conversion of a *liquid* into *vapour*, without necessarily reaching the *boiling point*; used in concentrating *solutions* by evaporating off the *solvent*. As it is the fastest moving *molecules* that escape from the surface of a liquid during evaporation, the average *kinetic energy* of the remaining molecules is reduced, and therefore evaporation causes cooling.

evaporometer See *atmometer*.

even-even nucleus A *nucleus* that contains both an even number of *protons* and an even number of *neutrons*.

even-odd nucleus A *nucleus* that contains an even number of *protons* but an odd number of *neutrons*.

event horizon See *black hole*.

evolute A curve that is formed from the *locus* of the *centres of curvature* of another curve (the *involute*). The end of a stretched string from the evolute traces the involute.

evolution See *Darwin's theory of evolution*.

exa- Prefix denoting one million million million; 10^{18} . Symbol E, e.g. $E_m = 10^{18}$ metres.

excess (chem.) A greater quantity of one substance or *reagent* than is necessary to react with a given quantity of another.

excess electron An *electron* in a *semiconductor* donated by an impurity, which is not required in the bonding system of the *crystal* and which is therefore available for *conduction* ('excess conduction').

exchange force 1. The type of *force* that holds *nucleons* together in the *nucleus* of an *atom*, visualized as the exchange of *mesons* between the nucleons. 2. A force occurring in ferromagnetic materials. See *ferromagnetism*.

exchanges, Prevost's theory of Bodies at all *temperatures* are constantly radiating *energy* to each other, those at constant temperature receiving in a given time as much energy as they emit.

excimer An excited *dimer*, formed by the association of excited and unexcited *molecules* (see *excitation*), which in the *ground state* would remain dissociated. Excimer *fluorescence* occurs in many *polycyclic hydrocarbons*.

excitation The addition of *energy* to a *nucleus*, an *atom*, or a *molecule*, transferring it from its *ground state* to a higher *energy level*. The 'excitation energy' is the difference in energy between the ground state and the excited state.

- exciton** A non-conduction, non-localized, excited *electron* state in a *semiconductor*. It may be regarded as a bound *electron-hole* pair, or alternatively as an atomic *excitation* passed from *atom* to *atom*.
- exclusion principle** See *Pauli exclusion principle*.
- exocrine glands** Glands that discharge their secretions into ducts, such as tear and salivary glands.
- exoenzyme** An *enzyme* that functions outside the *cell* that produces it, e.g. *pepsin*.
- exoergic process** An *exothermic process* (often applied in the context of a *nuclear reaction*).
- exosmosis** Outward osmotic flow. See *osmosis*.
- exosphere** The outermost layer of the *Earth's atmosphere*, in which the *density* is such that an air *molecule* moving directly outwards has a 50% chance of escaping rather than colliding with another molecule. The exosphere lies beyond the *ionosphere* and starts some 400 kilometres above the *Earth's surface*. See Fig. 44 under *upper atmosphere*.
- exothermic process** A process in which *energy* in the form of *heat* is released.
- expansion, coefficient of 1.** Linear. The increase in length per unit length, caused by a rise in *temperature* of 1°C . 2. Area (superficial expansion). The increase in area per unit area caused by a rise in *temperature* of 1°C . 3. Volume. The increase in *volume* per unit volume caused by a rise in *temperature* of 1°C . For *isotropic media*, the area and volume coefficients are approximately double and treble the linear coefficients respectively, for the same substance.
- expansion of gases** A *perfect gas* expands by $1/273$ of its volume at 0°C . for each degree rise in *temperature*, the *pressure* being constant (*Charles' Law*). Real gases obey this law only approximately at ordinary pressures, but the approximation becomes more and more valid as the pressure is reduced, i.e. as the gas tends towards a *perfect gas*.
- expansion of liquids** The directly observed expansion is the *apparent expansion*, since the vessel containing the *liquid* also expands. The coefficient of true expansion is the sum of the coefficient of apparent expansion, and the coefficient of volume expansion of the containing vessel.
- expansion of the Universe** The widely accepted theory that the Universe is expanding, i.e. that clusters of *galaxies* are receding from each other. It is based upon the evidence of the *red shift* (see also *Doppler effect*) and the theory of *relativity*. See *Hubble's constant*.
- explicit function** (math.) A variable quantity, x , is said to be an explicit function of y , when x is directly expressed in terms of y .
- explosion** A violent and rapid increase of *pressure* in a confined space. It may be caused by an external source of *energy* (e.g. *heat*) or by an internal *exothermic chemical reaction* in which relatively large

EXPLOSIVES

volumes of gases are produced. Explosions may also occur as the result of the release of internal energy during an uncontrolled *nuclear reaction* (either *fission* or *fusion* or both).

explosives Substances that undergo a rapid chemical change, with production of gas, on being heated or struck. The *volume* of gas produced being very great relative to the bulk of the *solid* explosive, great *pressures* are set up when the action takes place in a confined space.

exponent (math.) The number indicating the *power* of a quantity. Thus the exponent of x in x^4 is 4.

exponential The mathematical *series*,

$$e^x = 1 + x + x^2/2! + x^3/3! + \dots x^n/n!$$

is called an exponential series. When $x = 1$,

$$e = 1 + 1 + \frac{1}{2} + \frac{1}{6} + \frac{1}{24} + \dots = 2.718\ 28 \text{ (approx.)}.$$

The function of x , defined by $y = e^x$ is called an exponential function and e^x is the exponential x . The constant e is the base of natural or Naperian *logarithms*.

exposure meter (phot.) A *photoelectric cell* operating a suitable indicating meter, used in *photography* to assess the amount of *light* available, so that the correct shutter speed and *aperture* may be chosen for a given 'speed' of *film*.

expression (math.) A representation of a value, or relationship, in symbols.

extender An *inorganic* powder added to *paints* to improve such properties as *film* formation, and to avoid settlement on storage. Also used in the *plastics* industry with reference to substances added to *glues* or synthetic *rubbers* that reduce their cost or to some extent modify their properties (e.g. *viscosity*).

extensometer An instrument for measuring the extension produced in a body under an applied *stress*.

extinction coefficient A measure of the amount of *light* absorbed by a substance in *solution*. If light of intensity I_0 is passed through a distance d of a solution containing a *molecular concentration* c of the dissolved substance, so that its intensity is reduced to I_T , then the extinction coefficient is given by:

$$[\log_{10}(I_0/I_T)]/cd$$

extraction The process of separating a desired constituent from a *mixture*, by means of selective *solubility* in an appropriate *solvent*. Also used to describe any process by which a pure *metal* is obtained from *ore*.

extraordinary ray See *ordinary ray*.

extrapolation The process of filling in values or terms of a series on either side of the known values, thus extending the range of values.

extremely high frequencies EHF. *Radio frequencies* in the range 30,000 to 300,000 *megahertz*.

extrinsic semiconductor A *semiconductor* in which the *carrier* density results mainly from the presence of impurities or other imperfections, as opposed to an *intrinsic semiconductor* in which the electrical properties are characteristic of the *ideal crystal*.

eye-piece In optical instruments, the *lens* or system of lenses nearest the observer's eye; generally used to view the image formed by the *objective*.

F

face-centred See *body-centred*.

factor (math.) A number or quantity is exactly divisible by its factors; thus the factors of 12 (i.e. the *integral* or whole-number factors) are 1, 2, 3, 4, 6, 12.

factor, prime The prime factors of a quantity are the *prime numbers* that, when multiplied together, give the quantity. Thus, the prime factors of 165 are 3, 5, and 11.

factorial The *product* of a number and all the consecutive positive whole numbers below it down to 1. Thus, factorial 5, written $5!$ or $5 = 5 \times 4 \times 3 \times 2 \times 1 = 120$.

faculae Large bright areas of the *photosphere* of the *Sun*, whose *temperatures* are higher than the average of the *Sun's* surface.

Fahrenheit-scale of temperature. The *temperature* scale in which the *melting point* of ice is taken as 32°F . and the *boiling point* of water under standard atmospheric pressure (760 mm) as 212°F . $9^{\circ}\text{Fahrenheit degrees} = 5^{\circ}\text{Celsius degrees}$. To convert degrees F. to degrees C., subtract 32 from the F. value, multiply by 5, and divide by 9; to convert degrees C. to degrees F., multiply by 9, divide by 5, then add 32 to the result. Named after G. D. Fahrenheit (1686-1736).

Fajans' rules See *rules of Fajans*.

fall-out *Radioactive* substances deposited upon the surface of the Earth from the *atmosphere*. Three types of fall-out, subsequent to the *explosion* of a *nuclear weapon*, are recognized. 'Local fall-out' as a result of which large particles from the fire ball are deposited within a range of approximately 100 miles during the first few hours after the explosion. 'Tropospheric fall-out', during which fine particles are deposited around the globe, in the approximate *latitude* of the explosion, within a week or so. 'Stratospheric fall-out' consisting of the ultimate worldwide deposition, over a period of years, of the particles that were carried by the explosion into the *stratosphere*.

farad The derived *SI unit* of *capacitance* defined as the capacitance of a *capacitor* between the plates of which there appears a *potential difference* of 1 *volt* when it is charged with 1 *coulomb* of electricity. Symbol F (equal to ampere seconds per volt). Equivalent to 10^9 *electromagnetic units* and 8.99×10^{11} *electrostatic units*. The practical unit is the microfarad, which is 10^{-6} farad. Named after M. Faraday (1791-1867).

Faraday constant F . The quantity of *electricity* equivalent to unit *amount of substance* (one *mole*) of *electrons*, i.e. the product of *Avogadro's constant* and the charge on an electron. It has the value $9.648\,670 \times 10^4$ *coulombs* per mole.

Faraday effect Faraday rotation. The rotation of the plane of vibration (see *polarization of light*) of polarized light on traversing an *isotropic* transparent medium placed in a *magnetic field* possessing a component in the direction of the light ray. Although originally restricted to light, the Faraday effect is now known to apply to other *electromagnetic radiations*. Thus, the plane of polarization of a *radar pulse* travelling through the *ionosphere* is rotated by the combined effects of the *ionization* and the Earth's magnetic field (see *magnetism, terrestrial*). By reflecting radar pulses from the *Moon*, or other Earth *satellites*, and measuring the total rotation, the extent of the ionization in the ionosphere can be calculated.

Faraday's laws See *electrolysis, Faraday's law of*.

fast fission See *fast neutrons*.

fast neutrons Neutrons resulting from *nuclear fission* that have lost little of their *energy* by collision and therefore travel at high speeds. It is usual to describe neutrons with energies in excess of 0.1 MeV as 'fast'. However, fission induced by fast neutrons is often described as 'fast fission' and in this context the neutrons are so described if they have energies in excess of the fission threshold of $^{238}_{92}\text{U}$, i.e. above 1.5 MeV.

fast reactor A *nuclear reactor* in which little or no *moderator* is used and in which, therefore, the *nuclear fissions* are caused by *fast neutrons*.

fathom 6 feet. Used as a unit of marine depth.

fathometer A depth-sounding instrument. The depth of water is measured by noting the time the *echo* of a *sound* takes to return from the sea bed.

fatigue of metals The deterioration of *metals* owing to repeated stresses above a certain critical value; it is accompanied by changes in the crystalline structure of the metal.

fats and oils Simple *lipids* consisting of mixtures of various *glycerides* of *fatty acids*, which occur in plants and animals and serve as storage materials. The distinction between fats and oils (as distinct from *mineral oils*, which are *hydrocarbons*) is one of *melting point*; the term oil is usually applied to *glycerides* *liquid* at 20°C., the others being termed fats.

fatty acids *Monobasic organic acids* having the general formula R.COOH , where R is hydrogen or a group of carbon and hydrogen atoms. The *saturated* fatty acids have the general formula $\text{C}_n\text{H}_{2n+1}\text{COOH}$. Many fatty acids occur in living things, usually in the form of *glycerides* in *fats and oils*.

febrifuge See *antipyretic*.

feedback In general, the coupling of the output of a process to the input. In 'negative feedback' a rise in the output *energy* is arranged to cause a decrease in the input energy (e.g. a *governor*). In 'positive feedback' a rise in the output energy is caused to reinforce

FEHLING'S SOLUTION

the input energy. In particular, these terms are applied to electronic *amplifiers*, in which a portion of the output energy is used to reduce or increase the amplification, by reacting on an earlier stage according to the relative *phase* of the return.

Fehling's solution A solution of *cupric sulphate*, CuSO_4 , *sodium hydroxide*, NaOH , and *potassium sodium tartrate* (*Rochelle salt*). Used for the detection and estimation of certain *sugars* and other *reducing agents*, which act upon the solution with the formation of a red precipitate of *cuprous oxide*, Cu_2O . Named after Herman Fehling (1812-85).

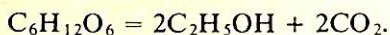
feldspar *felspar*. A large group of rock-forming *minerals* consisting chiefly of *aluminosilicates* of potassium and sodium. Constituents of *granite* and other primary rocks.

femto- Prefix denoting one thousand million millionth; 10^{-15} . Symbol *f*.

Fermat's principle of least time The path taken by a ray of *light* or other *wave motion* in traversing the distance between any two points is such that the time taken is a minimum. Named after Pierre de Fermat (1601-65).

ferment *Enzyme*. Any substance that will produce *fermentation*.

fermentation A chemical change brought about in organic substances by living *organisms* (*yeast*, *bacteria*, etc.) as a result of their *enzyme* action. Usually applied to the alcoholic fermentation produced by the action of *zymase* on certain *sugars*, giving *ethanol* and *carbon dioxide* according to the equation



fermi A unit of length, used in *nuclear physics*, equal to 10^{-13} cm. Named after Enrico Fermi (1901-54).

Fermi-Dirac statistics The branch of *statistical mechanics* used with systems of identical particles having the property that their *wave function* changes sign if any two particles are interchanged. See *fermions*. Named after Enrico Fermi (1901-54) and P. A. M. Dirac (b. 1902).

fermions Particles that conform to *Fermi-Dirac statistics*. The numbers of fermions are conserved throughout all nuclear interactions, but they are divided into two groups, *baryons* and *leptons*, which are distinguished from each other in that members of one group cannot transform into members of the other group. All fermions have *spin* $\frac{1}{2}$. See Appendix, Table 6.

fermium *Fm*. *Transuranic element*. At. No. 100. The most stable *isotope*, $^{257}_{100}\text{Fm}$, has a *half-life* of only 80 days.

ferrate A *salt* of the hypothetical ferric acid, H_2FeO_4 .

ferric Containing *tervalent* (trivalent) iron. Ferric *salts* are usually yellow or brown in colour.

ferric alum Iron alum. See *ferric potassium sulphate*.

ferric chloride $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$. A brown-yellow *deliquescent* crystalline salt. Used as a *mordant* and in medicine.

ferric oxide Fe_2O_3 . A red *insoluble* substance that occurs naturally as *haematite*. M.p. 1565°C ., used as a *mordant* and a *pigment*.

ferric potassium sulphate Ferric alum. $\text{Fe}_2(\text{SO}_4)_3 \cdot \text{K}_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$. A violet *soluble* crystalline *double salt* used in chemical analysis.

ferricyanide A salt of the unstable ferricyanic acid, $\text{H}_3\text{Fe}(\text{CN})_6$, e.g. *potassium ferricyanide*.

ferrimagnetism The type of *magnetism* occurring in materials in which the *magnetic moments* of adjacent atoms are anti-parallel, but of unequal strength, or in which the number of magnetic moments orientated in one direction outnumber those in the reverse direction. Ferrimagnetic materials therefore have a resultant magnetization similar to that of *ferromagnetism*. Typical ferrimagnetic materials are the *ferrites*.

ferrite 1. The name applied to several types of iron ore. 2. A salt of the hypothetical 'ferrous acid', derived from *ferric oxide*, Fe_2O_3 . 3. Pure *alpha-iron*, or solid solutions of which *alpha-iron* is the solvent.

ferrites A group of *ceramic* materials that exhibit the property of *ferrimagnetism*. They consist of iron oxide to which small quantities of *transition metal* oxides (e.g. cobalt and nickel oxides) have been added. The *spinel* ferrites have the formula $\text{MO} \cdot \text{Fe}_2\text{O}_3$ where M is a *divalent* transition metal ion. More complex barium-containing ferrites have also been manufactured. By suitable combinations of metallic oxides, ferrites can be made that exhibit *ferromagnetism*, but as they are electrical *insulators* and therefore do not suffer from the effects of *eddy currents*, they can be used as cores in coils and *transformers* in *electronic* equipment at *frequencies* that would be impossible with ordinary ferromagnetic materials. Ferrites are also used in the construction of memory circuits in *computers* and, on account of their light weight, in the electrical equipment of aircraft.

ferritin A *protein* found in the liver and spleen that contains iron. It acts as a reservoir of iron for the whole body.

ferro- Prefix denoting iron, especially in names of *alloys*; e.g. *ferro-manganese*.

ferroaluminium An *alloy* of aluminium (up to 80%) and iron.

ferrochrome An *alloy* of chromium with 30%-40% iron, obtained by the reduction of *chromite* with carbon in an electric furnace.

ferrocyanide A salt of the unstable ferrocyanic acid, $\text{H}_4\text{Fe}(\text{CN})_6$, e.g. *potassium ferrocyanide*.

ferroelectrics *Dielectric* materials that have electrical properties analogous to certain magnetic properties such as *hysteresis*, e.g. *barium titanate* and *potassium sodium tartrate* (*Rochelle salt*).

FERROMAGNETIC SUBSTANCES

Ferroelectric materials usually also have piezoelectric properties (see *piezoelectric effect*).

ferromagnetic substances See *ferromagnetism*.

ferromagnetism The *metals* iron, cobalt, nickel, and certain *alloys* are vastly more magnetic than any other known substance: these metals are said to be ferromagnetic. Ferromagnetism is due to unbalanced *electron spin* in the inner *electron orbits* of the *elements* concerned (see *atom, structure of*), which gives the *atom* a resultant *magnetic moment*. The ionic spacing in ferromagnetic *crystals* is such that very large *forces*, called *exchange forces*, cause the alignment of all the individual magnetic moments of large groups of atoms to give highly *magnetic domains*. In an unmagnetized piece of iron, these domains are oriented at random, their magnetic axes pointing in all directions. The application of an external field serves to line up the domain axes, giving rise to the observed magnetism. Ferromagnetic substances have very large *magnetic permeabilities*, which vary with the strength of the applied field. A given ferromagnetic substance loses its ferromagnetic properties at a certain critical temperature, the *Curie temperature* for that substance.

ferromanganese An alloy of manganese (70%-80%) and iron.

ferrosilicon An alloy of silicon (15%) and iron, used in special *steels*.

ferrotungsten An alloy of tungsten (up to 80%) and iron.

ferrous Containing *bivalent* (divalent) iron; more loosely, pertaining to iron. Ferrous *salts* are generally pale green in colour.

ferrous sulphate Green vitriol, copperas. $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. A pale green crystalline *soluble salt*. Made by dissolving scrap iron in dilute *sulphuric acid*. Used in *dyeing*, *tanning*, and *ink* manufacture.

fertile material *Isotopes* that can be transformed into *fissile material* by the absorption of *neutrons* (e.g. $^{238}_{92}\text{U}$, $^{232}_{90}\text{Th}$).

fertilization The union of two sexually dissimilar *gametes* to form a *zygote*.

fertilizers Materials put into the *soil* to provide *compounds of elements* essential to plant life; more particularly nitrogen, phosphorus, and potassium. Nitrogen is provided in the form of *nitrates*, *ammonium salts*, *calcium cyanamide*, etc. (see *fixation of atmospheric nitrogen*); phosphorus is added in the form of *superphosphate*, *basic slag*, various *phosphates*, etc. Potassium is obtained from natural potassium salts. Products of organic *decomposition* and waste, manure, etc., contain these and other necessary elements and form valuable fertilizers.

FET See *field-effect transistor*.

Fibreglass* See *glass fibre materials*.

fibrin An *insoluble* substance precipitated in the *blood* of vertebrates in the form of a meshwork of fibres during the process of clotting. Fibrin is formed when *thrombin* acts upon *fibrinogen*.

- fibrinogen** A *soluble protein* found in the *blood* of vertebrates that causes clotting of the blood by the action of the *enzyme thrombin* as a result of which *fibrin* is formed.
- fidelity** A measure of the *frequency* response of a *sound-producing* system. 'High fidelity' systems are usually taken to be those that are capable of reproducing frequencies up to 12 000 *hertz* without distortion.
- field** The region in which an electrically charged body (see *electric field*), a magnetized body (see *magnetic field*), or a massive body (see *gravitational field*) exerts its influence. A field is thus a model for representing the way in which a *force* can exist between bodies not in contact.
- field coil** A coil of wire used for magnetizing an *electromagnet*, e.g. in a *dynamo*.
- field-effect transistor (FET)** A type of *transistor* that is in wide use for a variety of purposes. The two main forms are the junction field-effect transistor (JUGFET) and the insulated-gate field-effect transistor (IGFET). The former consists of a wafer of *semiconductor* material flanked by two highly doped layers of opposing types (n^+ and p^+). Electrons from the *source* travel through a channel to the *drain*, the flow being controlled by a *gate*. In the insulated-gate type, a wafer of semiconductor has an insulating layer formed on its surface between two highly doped regions of opposite polarity, which form the source and the drain. A conductor attached to the top of the insulating layer forms the gate.
- field emission** The emission of *electrons* from an unheated surface as a result of a strong *electric field* existing at that surface.
- field-emission microscope** A type of microscope for observing the surface structure of a solid. A high negative voltage ($>10\text{kV}$) is applied to a metal tip placed at the centre of a spherical fluorescent screen in a vacuum. *Field emission* from the tip produces electrons, which create an enlarged image on the screen. As resolution is limited by the vibrations of the metal atoms, the tip is usually cooled with liquid helium.
- field guidance** A method of guiding a missile to a point within a *field* by means of the properties of that field. The field may be natural (e.g. a *gravitational field*) or artificial (e.g. an *electromagnetic* or *radio field*).
- field ionization** The *ionization* of atoms or molecules at the surface of an unheated solid as a result of a strong *electric field* existing at that surface. *Electrons* are transferred from the atoms or molecules to the solid, producing positive ions.
- field-ionization microscope** A similar type of microscope to the *field-emission microscope* except that a high positive voltage is applied to the metal tip and instead of a vacuum the tip is surrounded by a low pressure of helium gas. The image is formed on the fluorescent

FIELD LENS

screen by the helium *ions* striking it. The resolution can be made sufficiently high for individual atoms to be distinguished.

field lens The *lens* in the *eye-piece* system of optical instruments farthest from the eye.

field magnet A *magnet* that provides a *magnetic field* in the *dynamo*, *electric motor*, or other electrical machine.

filament A thin thread. In incandescent *electric light bulbs* and *thermionic valves*, the filament is a wire of tungsten or other *metal* of high *melting point*, which is heated by the passage of an *electric current*.

file (computers) A body of information that has a describable structure, allowing all, or part, of it to be retrieved from the *store* (or *backing storage*) on demand.

filler A *solid* substance added to synthetic *resins*, *paints*, and *rubbers*, either to modify their properties or to reduce their cost.

film 1. (chem.) A thin layer of a substance formed on the surface of a *liquid* or at the interface between two immiscible liquids, usually only a few *molecules* thick. 2. (phot.) A flexible strip (usually *cellulose acetate* or a *polyester*) coated with a light-sensitive *emulsion*. See *photography*.

film badge A badge containing a masked photographic *film* worn by workers in contact with *ionizing radiations* to indicate the extent of their exposure to these radiations.

filter 1. (chem.) A device for separating *solids* or suspended particles from *liquids*. It consists of a porous material (e.g. filter-paper) through the pores of which only liquids and dissolved substances can penetrate. 2. (phys.) A material or device inserted in the path of an *electromagnetic radiation* to alter its *frequency* distribution.

filter press An apparatus used for carrying out *filtration*; it consists of a series of frames (metal or wooden) the two sides of which are covered with filter cloth. The frames are clamped together and the *liquid* to be filtered is pumped into them so that the *solid* residue forms a cake between the cloths while the *filtrate* is drained off.

filter pump A type of *vacuum pump* used to assist *filtration*. It is similar in principle to the *condensation pump*. A jet of water entrains air molecules, thus reducing the pressure below the filter paper or filter bed. It does not reduce the pressure below the *vapour pressure* of water.

filtrate A clear *liquid* after *filtration*; a substance that has been filtered, and contains no suspended matter.

filtration The process of separating *solids* from *liquids* by passing them through a *filter*.

finder A small low-powered *telescope* fixed parallel to the axis of a large telescope (usually astronomical) so that the object to be observed may be located and set in the field of vision of the large telescope.

fineness of gold The quantity of gold in an *alloy* expressed as parts per thousand. Thus gold with a fineness of 900 is in alloy containing 90% gold. See also *carat*.

fine structure The structure of certain *spectrum* lines when they are examined under high resolution. Single lines may be resolved into two or more closely spaced lines. See also *hyperfine structure*.

fire A *chemical reaction* accompanied by the evolution of *heat*, *light*, and *flame* (i.e. a glowing mass of *gas*). It is generally applied to the chemical combination with oxygen of carbon and other *elements* constituting the substance being burnt. See *combustion*.

fireclay Clay consisting principally of *aluminium oxide*, Al_2O_3 , and *silica*, SiO_2 , which will only soften at high *temperatures* and which is therefore used as a *refractory* material. Fireclays often occur beneath coal seams.

fire-damp An explosive mixture of *methane* (CH_4) and air, formed in coal mines.

fire extinguishers Hand devices for extinguishing *fires* in their early stages. They are usually classified according to the type of fire they are intended to combat, i.e. Class A fires (*paper*, wood, furnishings, and other common solid combustibles) and Class B fires (inflammable *liquids*, e.g. *petrol*, *paraffin*, etc.). Class A fires (which do not involve electrical equipment) are best combated with *water* under pressure delivered from extinguishers in which the water is expelled by stored pressure or by *carbon dioxide* produced by the action of *sulphuric acid* on *sodium hydrogen carbonate* (the 'soda-acid' type). Also in use are dry powder extinguishers (consisting of finely ground sodium or potassium hydrogen carbonate), and the *halogenated hydrocarbon* type, e.g., bromochlorodifluoromethane (BCF) or chlorobromomethane (CB). These halogenated hydrocarbons, however, like the fires themselves, produce *toxic* products of *combustion*, but BCF and CB are less toxic than *carbon tetrachloride* (CTC), as used in the older extinguishers.

Class B fires are best extinguished by the dry powder extinguishers, halogenated hydrocarbon extinguishers, or by carbon dioxide extinguishers. Also used are air-foam extinguishers (based on slaughterhouse products high in *protein*) or chemical foam extinguishers (based on solutions of *aluminium sulphate* and sodium hydrogen carbonate, which react together on mixing, evolving carbon dioxide and producing a *foam*).

Fischer-Tropsch process A process for the manufacture of *hydrocarbon oils* from *coal*, *lignite*, or *natural gas*. The process essentially consists of the *hydrogenation* of *carbon monoxide*, CO , in the presence of *catalysts*; this results in the formation of hydrocarbons and *steam*. Named after F. Fischer (d. 1948) and H. Tropsch (d. 1935).

FISSILE MATERIAL

fissile material *Isotopes* that are capable of undergoing *nuclear fission*.

Sometimes the term is restricted to isotopes that are capable of undergoing fission upon impact with a slow *neutron* (e.g. $^{233}_{92}\text{U}$, $^{235}_{92}\text{U}$, $^{239}_{94}\text{Pu}$).

fission, nuclear See *nuclear fission*.

fission products Both the stable and the unstable *isotopes* produced as the result of *nuclear fission*.

fission spectrum The *energy* distribution of the *neutrons* produced by the *nuclear fission* of a particular *fissile material*.

Fittig reaction Wurtz-Fittig synthesis. The synthesis of *alkylarene* hydrocarbons by the action of metallic sodium on a mixture of an *alkyl halide* and a halogenated *benzene* derivative.

Fitzgerald-Lorentz contraction The hypothesis put forward independently by Fitzgerald (1893) and Lorentz (1895) to explain the result of the *Michelson-Morley experiment* on the supposition that a body moving with high *velocity* through the *ether* would experience a contraction in length in the direction of the motion. This contraction was later shown to be a direct consequence of the theory of *relativity*. Named after G. F. Fitzgerald (1851-1901) and H. A. Lorentz (1853-1928).

fixation of atmospheric nitrogen The manufacture of *compounds* of nitrogen for use as *fertilizers*, from the free nitrogen in the air; it is made necessary by the increasing shortage of natural nitrogen compounds in the *nitrogen cycle*. This shortage is caused partly by increased cultivation of the *soil* due to the increase of populations, and partly by the loss of nitrogen compounds from animal waste products by sewage disposal into the sea. The first practical process was the *Birkeland and Eyde process*; the *Haber* and *Serpek processes* are now the main ones used. In addition, certain *bacteria* in the soil fix atmospheric nitrogen.

fixed air Former name for *carbon dioxide*, CO_2 .

fixed alkali Former name for *potassium* or *sodium carbonate*, to distinguish them from volatile alkali, ammonium carbonate.

fixed point Any accurately reproducible equilibrium *temperature*. Examples include the *ice point*, the *steam point*, and the *sulphur point*. See *International Practical Temperature Scale*.

fixed stars True *stars*; heavenly bodies termed fixed because they do not appear to alter their relative positions on the *celestial sphere*.

fixing, photographic Rendering that portion of the sensitive *film*, plate, or paper that has not been affected by *light*, insensitive to exposure, after *developing*. It is usually carried out by the action of *sodium thiosulphate*, $\text{Na}_2\text{S}_2\text{O}_3$ (*hypo*), which reacts with the unaffected *silver bromide* to give a *soluble double salt*, silver sodium thiosulphate, which is then washed away. See *photography*.

flame The glowing mass of *gas* produced during *combustion*.

flame photometry A development of the *flame test* used in qualitative analysis; photometric (see *photometer*) measurement of flame *emission* is used to determine the concentration of substances introduced into the flame.

flame test A *qualitative* test for the presence of an element by the colour it or its compounds give to a *Bunsen burner* flame. Sodium compounds colour a flame bright yellow; potassium, caesium, and rubidium give a violet colour; strontium and lithium a red colour; copper, thallium, and tellurium give a green colour, except copper *halides*, which give a blue colour.

flash photography See *spark photography*.

flash photolysis See *photolysis*.

flash point The lowest *temperature* at which a substance gives off sufficient inflammable *vapour* to produce a momentary flash when a small flame is applied.

flavoproteins Yellow conjugated *proteins* in which the *prosthetic group* is either flavin mononucleotide (FMN) or flavin adenine dinucleotide (FAD). Flavoproteins are *enzymes* of the *dehydrogenase* type.

Fleming's rules Mnemonics for relating the direction of motion, *flux*, and *E.M.F.* in electric machines. If the forefinger, second finger, and thumb of the right hand are extended at right angles to each other, the forefinger indicates the direction of the flux, the second finger the direction of the *E.M.F.*, and the thumb the direction of motion in an electric *generator*. If the left hand is used the digits indicate the conditions obtaining in an *electric motor*. Named after Sir John Ambrose Fleming (1849-1945).

flint Natural variety of impure *silica*, SiO_2 . 'Flints' of automatic lighters are composed of *pyrophoric alloys* of *metals* such as cerium and iron.

flint glass A variety of *glass* containing lead silicate; used for optical purposes.

flocculation The coagulation of finely divided particles into particles of greater mass.

flotation, principle of The *mass* of *liquid* displaced by a floating body is equal to the mass of the body. A particular case of *Archimedes' principle*.

flotation process The separation of a *mixture*, e.g. of *zinc blende*, ZnS , and *galena*, PbS , making use of the *surface tension* of *water*. Zinc blende is not easily wetted by water and floats, supported by the surface film of water, while galena sinks. In modern practice, special materials are added to the water to cause one of the constituents to float in the froth produced by aerating and agitating the water. See *froth flotation*.

flowers of sulphur A fine powder, consisting of very small *crystals* of

FLUE GAS

sulphur obtained by the *condensation* of sulphur vapour during *distillation* of crude sulphur.

flue gas The gaseous products of *combustion* from a boiler furnace consisting predominantly of *carbon dioxide*, *carbon monoxide*, oxygen, nitrogen, and *steam*. Analysis of the flue gases is used to check the efficiency of the furnace. See *Orsat apparatus*.

fluid A substance that takes the shape of the vessel containing it; a *liquid* or *gas*.

fluid drachm See *drachm*.

fluidics Fluidic logic. The study, design, and use of jets of fluid to carry out *amplification* and *logic* to perform tasks usually carried out by *electronics*. Fluidic systems, which depend on the flow of *fluids* instead of *electrons*, are about 10^6 times slower than electronics, but they can operate at higher *temperatures*. They are also unaffected by *ionizing radiations* and they are often cheaper and more reliable than corresponding electronic systems. They have therefore found use in *nuclear reactors* and *space rockets*.

fluidity The *reciprocal* of *viscosity*. The *c.g.s. unit* is the reciprocal of the *poise* known as the *rhe*.

fluidization (chem.) A technique used in industrial chemistry, in which a mass of solid particles is brought into a state of suspension by an upward stream of gas blown through it in a *reactor*. The material in the resultant 'fluidized bed,' which resembles a boiling liquid, is more accessible to chemical reactions, etc., than the same solid material in the static state.

fluid measure See *apothecaries' fluid measure*.

fluid ounce British measure of *volume* of *liquids*. 28.41 cc. See *apothecaries' fluid measure*.

fluon* See *fluorocarbons*.

fluorene *o*-diphenylenemethane. $C_{13}H_{10}$. A white crystalline *aromatic solid hydrocarbon*, m.p. $116^{\circ}C$. Used in the manufacture of *dyes* and *resins*.

fluorescein $C_{20}H_{12}O_5$. A dark red crystalline *organic compound*, m.p. $314^{\circ}C$. It dissolves in *alkaline solutions* to give a *liquid* of intense green *fluorescence*. Used as an *indicator* and in *dyes*.

fluorescence A form of *luminescence* in which certain substances (e.g. *quinine sulphate solutions*, *paraffin oil*, *fluorescein solutions*) are capable of absorbing *light* of one *wavelength* (i.e. *colour*, when in the visible region of the *spectrum*) and in its place emitting light of another wavelength or colour. Unlike *phosphorescence*, the phenomenon ceases immediately the source of light is cut off.

fluorescent lamp A *light source* consisting of a glass tube the inside of which is coated with a fluorescent substance (see *fluorescence*). The tube contains *mercury vapour* and is fitted with a *cathode* and *anode* between which a stream of *electrons* can be made to flow by the application of a suitable *voltage*. When the *mercury atoms* are

struck by the electrons they emit *ultraviolet radiation*, which is converted to visible radiation by the fluorescent substance on the tube walls.

fluoridation The addition of minute quantities of *fluorides* to drinking water supplies to give protection against caries (decay) in the teeth of growing children. 1 part per million of fluoride ion is usually added.

fluoride A salt of *hydrofluoric acid*. See *fluoridation*.

fluorination The introduction of a fluorine atom into a compound by *substitution* or by an *addition reaction*. Compare *fluoridation*.

fluorine F. Element. A.W. 18.9984. At. No. 9. A pale yellowish-green gas, resembling chlorine but more *reactive*. It occurs combined as *fluorspar* and as *cryolite* and is made by the *electrolysis* of a solution of *potassium hydrogen difluoride* in *anhydrous hydrogen fluoride*. The fluorine *organic compounds*, made by replacing hydrogen in organic compounds by fluorine, are assuming considerable industrial importance. See *fluorocarbons*.

fluorite See *fluorspar*.

fluorocarbons A group of *synthetic organic compounds* (both *aliphatic* and *aromatic*) in which some or all of the hydrogen atoms have been substituted by fluorine atoms. Many of these compounds and their derivatives are nonflammable, chemically resistant, and immiscible with water or oil. *Polytetrafluoroethylene* (Teflon* and Fluon*) is a *polymer* used as a *plastic*, while the Freons* are *monomers* used as *refrigerants* and *solvents*.

fluoroscope A fluorescent screen (see *fluorescence*) for the direct visual observation of X-ray images; used diagnostically in medicine.

fluorosilicic acid *Hydrofluosilicic acid*. H_2SiF_6 . An acid that is only stable in the form of its fuming *aqueous solution*. Used as a *disinfectant* and wood preservative.

fluorspar Natural calcium fluoride, CaF_2 , consisting of colourless *crystals*, often coloured by impurities. Used as a source of fluorine and its *compounds*.

flux (chem.) A substance added to assist fusion.

flux (phys.) The rate of flow of mass or energy per unit area normal to the direction of the flow. See also *magnetic flux*; *electric flux*; *luminous flux*. In *nuclear physics*, it is the product of the number of particles per unit volume and their average velocity.

flux density The *magnetic flux* or *luminous flux* per unit of cross-sectional area. The S.I. unit of magnetic flux density is the *tesla*.

fluxmeter An instrument for the measurement of *magnetic flux*. Essentially a moving coil *galvanometer* so designed that the coil experiences negligible restoring *torque* from its suspension system. A change in the magnetic flux through a flux coil connected to the galvanometer induces a current in the coil, thus causing a deflection of the galvanometer.

***f*-number of a lens** The ratio of *focal length* to *diameter*, e.g. *f*8 means that the focal length is eight times the diameter. For any particular lens, the smaller the *f*-number the larger the *aperture*. The reciprocal of the *f*-number is called the 'relative aperture'.

foam A *colloidal* suspension of a *gas* in a *liquid*.

focal length The distance from the *optical centre* or pole to the principal focus of a *lens* (see Fig. 25 under *lens*), or spherical mirror (see Fig. 27 under *mirrors, spherical*). The focal length of a spherical mirror is half its *radius of curvature*.

focus 1. (phys.) The point at which converging rays, usually of *light*, meet (real focus); or a point from which diverging rays are considered to be directed (virtual focus). The 'principal focus' of a *lens* (see Fig. 25 under *lens*) or spherical mirror (see Fig. 27 under *mirrors, spherical*) is the point on the principal axis through which rays of light parallel to the *principal axis* will be refracted or reflected. 2. (math.) One of the fixed points used to define a curve, by a linear relationship with the distance from one of these fixed points to any point on the curve. See *ellipse*; *parabola*; *hyperbola*.

fog The effect caused by the *condensation* of *water vapour* upon particles of dust, soot, etc.

folic acid Pteroylglutamic acid, P.G.A., vitamin B_c. C₁₉H₁₉N₇O₆. A yellow crystalline substance forming part of the *vitamin B* complex, used in the treatment of anaemia. Also known as vitamin M.

food preservation The prevention of chemical *decomposition* and of the development of harmful *bacteria* in foods. It is generally effected by the sterilization of the food (i.e. by the destruction of bacteria in it) by heating in sealed vessels, i.e. canning; or by making the conditions unfavourable for the development of bacteria, by pickling, drying, freezing, smoking, etc.

foot British unit of length; one-third of a *yard*; 0.3048 *metre*.

foot-candle Unit of *illumination*. One *lumen* per square foot. Now replaced by the *lux*.

foot-lambert A unit of *luminance*. The luminance of a uniform diffuser emitting one *lumen* per square foot. This unit is now obsolete, except in the U.S.A.

foot-pound A practical unit of *work*. The work done by a *force* of 1 pound weight acting through a distance of 1 foot.

foot-poundal A unit of *work* in the *f.p.s. system*; the work done by a *force* of 1 *poundal* acting through a distance of 1 foot.

forbidden band See *energy bands*.

force An external agency capable of altering the state of rest or motion in a body; measured in *newtons* (*SI units*), *dynes* (*c.g.s. units*), or *poundals* (*f.p.s. units*). The force, *F*, required to produce an *acceleration*, *a*, in a mass, *m*, is given by $F = ma$. If *m* is in *kilograms*, *a* in m s^{-2} , *F* will be in *newtons*.

forces, parallelogram of See *parallelogram of forces*.

forces, triangle of See *triangle of forces*.

formaldehyde HCHO . A gas with an irritating smell: it is very soluble in water, a 40% solution being known as *formalin*. Made by the oxidation of methanol. Used in the manufacture of plastics and dyes, in the textile industry, in medicine, and as a *disinfectant*.

formalin A 40% solution of formaldehyde, used as a *disinfectant*.

formate A salt or ester of *formic acid*.

formic acid Methanoic acid. HCOOH . A colourless, corrosive fuming liquid with a pungent smell. M.p. 8.4°C ., b.p. 100.5°C . It occurs in various plants and in ants; it is made industrially from sodium formate, HCOONa , which is produced by the action of carbon monoxide, Co , on sodium hydroxide, NaOH . Used in dyeing, tanning, and electroplating.

formula (chem.) The representation of a *molecule* or smallest portion of a *compound*, using *symbols* for the *atoms* of the *elements* which go to make up the molecule. E.g. the formula of water, H_2O , implies that the smallest portion of water that can exist independently consists of 2 hydrogen atoms chemically united with 1 oxygen atom. The *structural formula* represents the way in which the atoms in a molecule are joined by *valence bonds*. E.g. the structural formula of water is written $\text{H}-\text{O}-\text{H}$, indicating that 2 hydrogen atoms, having 1 valence each, are both attached to the *bivalent* oxygen atom. The *empirical formula* of a compound is its simplest formula, indicating only the numerical ratio of the atoms present in a molecule, but not necessarily their actual number. Thus the empirical formula of *hydrogen peroxide* is HO while its actual or *molecular formula* is H_2O_2 .

formula (math. and phys.) A statement of facts in a symbolical or general form, by substitution in which a result applicable to particular data may be obtained. Thus the time of swing of a *pendulum* (T) is given by the formula $T = 2\pi\sqrt{l/g}$, showing the connection between length (l) and time of swing. (g is the *acceleration of free fall*).

formyl The *univalent radical* $\text{O}=\text{CH}-$, derived from *formic acid*.

fortin barometer A mercury *barometer* that, used in conjunction with various correction tables, enables accurate measurements of atmospheric pressure to be made. Named after J. Fortin (1750-1831).

fossil The remains of an *organism* preserved in rocks in the *Earth's crust*. Usually only the hard parts (bones, shells, etc.) are so preserved, but occasionally remains of organisms having no hard parts have been recognized.

fossil fuels The remains of *organisms* embedded in the surface of the Earth, with high carbon and/or hydrogen contents, that are used by man as *fuels* (e.g. coal, oil, natural gas). Most of the energy obtained from the *combustion* of fossil fuels derives from the

FOUCAULT PENDULUM

exothermic conversion of carbon into *carbon dioxide* and of hydrogen into *water (steam)*.

foucault pendulum A *pendulum* consisting of a heavy weight attached to a long wire, which is free to swing in any direction. The slow turning of the *plane* of the pendulum's swing is a demonstration of the *Earth's* rotation. Named after its inventor, J. B. L. Foucault (1819-68).

fourier analysis The expansion of a mathematical *function* or of an experimentally obtained curve in the form of a trigonometric series. Used as a method of determining the harmonic components of a complex periodic wave. Named after J. B. J. Fourier (1768-1830).

fourth dimension Ordinary *space* has three dimensions, i.e. length, breadth, and thickness, each one at right angles to both the others. Mathematically it is possible to write down equations, similar to those governing relations between points in ordinary three-dimensional space, but connecting any number of imaginary dimensions. These are sometimes said to refer to a 'hyperspace' of many dimensions. In dealing with a material particle, it is necessary to state not only where it is, but when it is there. Thus time is somewhat analogous to a dimension of space. *Relativity* has shown in particular in what manner time may be regarded as a fourth dimension, so that all real events take place in a four dimensional *space-time continuum*.

Fowler's solution A *solution* containing potassium arsenite; used in medicine.

f.p.s. system The foot-pound-second system of units. The British system of physical *units* derived from the three *fundamental units* of length, *mass*, and time, i.e. the *foot*, *pound mass*, and the *second*. It is now replaced, for scientific purposes, by *SI units*.

fractional crystallization The separation of a *mixture* of dissolved substances by making use of their different *solubilities*. The *solution* containing the mixture is evaporated until the least *soluble* component crystallizes out.

fractional distillation Fractionation. The separation of a *mixture* of several *liquids* that have different *boiling points*, by collecting separately 'fractions' boiling at different *temperatures*.

fractionating column A long vertical column, containing rings, plates, or bubble caps, that is attached to a *still*. As a result of internal *reflux* a gradual separation takes place between high and low boiling 'fractions' of a liquid *mixture*.

fractionation The separation of a *mixture*, usually of chemically related or otherwise similar components, into fractions of different properties. The term is usually applied to *fractional distillation*.

frame of reference A set of reference axes for defining the position of a point or body in *space*. A frame of reference in a four-dimensional

continuum consists of an observer, a *coordinate system*, and a clock to correlate positions with times.

francium Fr. Element. At. No. 87 It has no known stable *isotope* and only one natural *radioactive isotope*, $^{223}_{87}\text{Fr}$ (*half-life* 21 mins.). It belongs to the *alkali metal group of elements*.

Frasch process A process for extracting sulphur from deposits deep down under sand. A series of concentric pipes is sunk down to the level of the sulphur deposit, *superheated steam* is forced down to melt the sulphur, which is then forced to the surface by compressed air blown down the centre pipe.

Fraunhofer diffraction The class of *diffraction* phenomena in which both the *light source* and the receiving screen are effectively at an infinite distance from the diffracting system. Compare *Fresnel diffraction*. Named after J. von Fraunhofer (1787-1826).

Fraunhofer lines Dark lines in the continuous *spectrum* of the *Sun*, caused by the absorption of certain *wavelengths* of the *white light* from the hotter regions of the Sun by chemical *elements* present in the cooler *chromosphere* surrounding the Sun.

free (chem.) Uncombined; it is applied to *elements* that occur as such.

free electron An *electron* that is not attached to an *atom*, *molecule*, or *ion*, but is free to move under the influence of an *electric field*.

free energy Gibbs Function. *G*. A *thermodynamic* quantity representing the *energy* that would be liberated or absorbed during a *reversible process*. Defined, under conditions of constant *temperature* and *pressure*, by $G = H - TS$, where *H* is the heat content (*enthalpy*), *T* the *thermodynamic temperature*, and *S* the *entropy*. Referred to chemical processes, the important quantity is not the absolute magnitude of *G*, but the change in free energy, ΔG (also called the *chemical affinity*), during a reaction, which is given by

$$\Delta G = \Delta H - T.\Delta S.$$

By convention, if a reaction gives out *heat*, ΔH will be negative (as the system is losing heat to the surroundings). Therefore, if $T.\Delta S$ is not large compared to ΔH , ΔG will also be negative indicating that the reaction will proceed to *chemical equilibrium*. When equilibrium has been attained, $\Delta G = 0$, and if ΔG is positive the reaction will only occur if energy is supplied in some way to force it away from equilibrium. As the entropy, *S*, is a measure of the molecular disorder of a system, and as a change of state involves a change of molecular orderliness, the term $T.\Delta S$ is dependent upon changes of state.

The Helmholtz Free Energy, *F*, is defined as $U - TS$, where *U* is the *internal energy*. Also, $\Delta F = \Delta U - T.\Delta S$ and for a reversible *isothermal* process ΔF represents the maximum work available. ΔF is sometimes called the 'work function'.

FREE RADICAL

free radical A group of *atoms* (see *radical*), which usually exists in combination with other atoms, but which may exist independently for short periods (short-lived free radicals) during the course of a *chemical reaction*, or for longer periods (free radical of long life) under special conditions.

freeze drying A process of drying heat-sensitive substances, such as food or *blood plasma*, by *freezing* and then removing the frozen water by volatilization at low *pressure* and *temperature*.

freezing Change of state from *liquid* to *solid*; it takes place at a constant *temperature* (*freezing point*) for any given substance under a given *pressure*. The freezing point normally quoted is that for standard atmospheric pressure.

freezing mixtures Certain *salts* that, when dissolved in *water* or mixed with crushed *ice*, produce a considerable lowering of *temperature*. The action depends upon absorption of *heat of solution* by the dissolving salt; in the case of mixtures in contact with ice, the *melting point* of ice is lowered in the presence of a dissolved substance; *latent heat* of fusion of ice is absorbed, and the salt dissolves in the melting ice.

freezing point The *temperature* of equilibrium between *solid* and *liquid* substance at a pressure of one standard atmosphere (760 mm mercury).

freezing-point depression See *depression of freezing point*.

French chalk Powdered *talc*.

Frenkel defect A *defect* in a *crystal lattice* caused by an *atom* or *ion* being removed from its normal position in the lattice (thus causing a *vacancy*) and taking up an *interstitial* position.

freons See *fluorocarbons*.

frequency The number of cycles, oscillations, or vibrations of a *wave motion* or oscillation in unit time, usually one second. In a wave motion the frequency is equal to the *velocity* of propagation divided by the *wavelength*. Symbol ν or f . The derived *SI unit* of frequency is the *hertz*.

frequency band A range of *frequencies* of *electromagnetic radiations* falling within prescribed limits. See Appendix, Table 10, for internationally agreed *radio frequency* bands.

frequency modulation FM. The type of *radio* transmission system in which the *frequency* of a *carrier wave* is modulated rather than its *amplitude* (as in *amplitude modulation*). It provides a method of transmission free from 'static' interference.

frequency of a vibrating string The fundamental *frequency*, f , of a stretched string of length l , under tension T , is given by

$$f = \sqrt{T/\pi p}/2rl$$

where r is the radius of the string and p its *density*.

fresnel A unit of *frequency* equal to 10^{12} hertz. Named after A. J. Fresnel (1788-1827).

Fresnel diffraction A class of *diffraction* phenomena in which the *light* source or the receiving screen, or both, are at a finite distance from the diffracting system. Compare *Fraunhofer diffraction*.

Fresnel lens An optical *lens* whose surface consists of a number of smaller lenses so arranged that they give a short *focal length*. Used in headlights, searchlights, etc. Named after A. J. Fresnel (1788-1827).

friable Easily crumbled.

friction The *force* that offers resistance to relative motion between surfaces in contact. See *tribology*.

friction, coefficients of If F_s = the frictional resistance when a body is on the point of sliding along a specified surface, F_k = the frictional resistance when steady sliding has been attained, and R = the perpendicular force between the surfaces in contact, the static coefficient of friction = F_s/R ; the kinetic coefficient = F_k/R .

Friedel-Crafts reaction Originally the *synthesis* of aromatic hydrocarbons by reacting alkyl halides with benzene derivatives in the presence of anhydrous aluminium chloride as a catalyst. It is now extended to include the addition of alkenes to, and the condensation of alcohols with, aromatic hydrocarbons in the presence of such catalysts as anhydrous ferric chloride, gallium chloride, boron trifluoride, and hydrogen fluoride.

froth flotation The separation of a mixture of finely divided minerals by agitating them in a froth of water and a frothing agent, so that some float and others sink. The process can be made selective by adjusting the nature of the froth with suitable surface active agents.

fructose Fruit sugar, laevulose. $C_6H_{12}O_6$. A sweet soluble crystalline hexose, m.p. 102° - $104^\circ C$. Occurs in sweet ripe fruits, in the nectar of flowers, and in honey.

frustum Any part of a solid figure cut off by a plane parallel to the base, or lying between two parallel planes.

fuel A substance used for producing heat energy, either by means of the release of its chemical energy by combustion (see fossil fuels) or its nuclear energy by nuclear fission.

fuel cell A cell for producing electricity by oxidation of a fuel, thus converting chemical energy directly into electrical energy. The fuel cell is similar to an accumulator but instead of needing recharging with electrical energy, it has to be fed with fresh fuel. The simplest fuel cell consists of supplies of gaseous oxygen and hydrogen brought together over catalytic electrodes. Other cells use hydrazine, ammonia, or methanol to provide the hydrogen. Interest in electric cars has stimulated fuel cell development. Although hydrogen-oxygen fuel cells can provide higher energy densities than zinc-air

FUEL ELEMENT

accumulators, because they are very bulky their energy per volume is little better than that of a lead accumulator.

fuel element An element of *nuclear fuel* for use in a *nuclear reactor*, usually uranium encased in a can.

Fuller's earth A variety of *clay-like* materials that absorb *oil* and *grease*. They consist of *hydrated silicates* of magnesium, calcium, aluminium, and sometimes other *metals*. Used in scouring textiles and in refining *fats and oils*.

full-wave rectifier A *rectifier* that converts the negative half wave of an *alternating current* into a positive half wave, so that both halves of the swing are able to deliver a unidirectional current.

fulminate A salt of the *unstable* fulminic acid, HONC, which is *isomeric* with *cyanic acid*; e.g. *mercuric fulminate*.

fulminate of mercury See *mercuric fulminate*.

fumalic acid $\text{HOOCCH}:\text{CHCOOH}$. A colourless crystalline substance, m.p. 287°C ., *isomeric* with *maleic acid*. Used in the manufacture of synthetic *resins* and in *baking powders*.

fumigation The destruction of *bacteria*, insects, and other pests by exposure to poisonous *gas* or *smoke*.

fuming nitric acid A brown fuming highly corrosive *liquid* consisting of *nitric acid* containing an excess of *nitrogen peroxide*. Used as an *oxidant* in *rockets* and in organic synthesis.

fuming sulphuric acid See *oleum*.

function (math.) One quantity y is said to be a function of another quantity x , written $y = f(x)$, if a change in one produces a change in the other. Thus, in the statement

$$y = 3x^2 + 5x \text{ (i.e. } f(x) = 3x^2 + 5x)$$

y is a function of x , and a change in the value of x produces a change in the value of y .

fundamental constants See Appendix, Table 2.

fundamental note (phys.) See *quality of sound*.

fundamental units The *units* in which physical quantities (e.g. *viscosity*, *surface tension*, etc.) are measured are not all independent; many of them are derived from a small number of fundamental or *base units*.

fungi Simple plants that contain no *chlorophyll*. They may consist of one *cell* or of many cellular filaments. They cause diseases of plants and of some animals, and also cause decay of food, fabrics, and timber. Certain fungi are used in *brewing* and *baking* and for the production of *antibiotics*.

fungicide A substance capable of destroying harmful *fungi*, such as moulds and mildews.

furan Furfuran. $\text{C}_4\text{H}_4\text{O}$. A five-membered *heterocyclic compound* consisting of a colourless *liquid*, b.p. 32°C . Used in organic synthesis and in the form of its *derivatives* in the manufacture of synthetic *resins*.

- furan resins** A group of synthetic *resins* obtained by the partial polymerization of *furfuryl alcohol* or by the condensation of *furfuryl alcohol* with *furfuraldehyde* or *formaldehyde*. Used as *adhesives*, metal coatings, etc.
- furfuraldehyde** Furfural. C_4H_3OCHO . A *liquid organic compound*, b.p. $161.7^\circ C$.; used as a *solvent* and in synthetic *resins*. See *furfural resins*; *furan resins*.
- furfural resins** *Thermosetting resins* obtained by the condensation of *furfuraldehyde* and *phenol* or its homologues. Used as an *adhesive* and in the manufacture of moulding materials, varnishes, etc.
- furfuryl alcohol** $C_4H_3OCH_2OH$. A yellowish *liquid*, b.p. $171^\circ C$., used in the manufacture of *furan resins*.
- fur in kettles** An *insoluble* gritty deposit, consisting mainly of the carbonates of calcium, magnesium, and iron; it is formed by the decomposition of the soluble bicarbonates of these metals when *hard water* is boiled.
- fuse, electrical** A device to prevent an unduly high *electric current* from passing through a *circuit*. It consists of a piece of wire made of *metal* of low *melting point*, e.g. tin, placed in series in the circuit. An excessive current will raise the *temperature* of the fuse wire sufficiently to melt it and thus break the circuit.
- fused** (chem.) In the molten state, usually applied to *solids* of relatively high *melting point*; or, having previously been melted and allowed to solidify.
- Fusel oil** A *mixture* of *butanol* and *iso-amyl alcohol* together with other organic substances; a *liquid* of unpleasant smell and taste. It is a *by-product* of the *distillation* of alcohol produced by *fermentation*.
- fusible alloys** Alloys of low *melting point*; generally *eutectic mixtures* of *metals* of low *melting point* such as bismuth, lead, tin, and cadmium. *Wood's metal* and *Lipowitz alloy* both contain all four and melt below the *boiling point* of water. Fusible alloys having a *melting point* a little above the *boiling point* of water are used in the construction of automatic sprinklers, *heat* from a fire melting the metal and releasing a spray of water.
- fusion** Melting; melting together.
- fusion, latent heat of** See *latent heat*.
- fusion, nuclear** See *nuclear fusion*.
- fusion bomb** See *nuclear weapons*.
- fusion mixture** A *mixture* of *anhydrous sodium* and *potassium carbonates*, Na_2CO_3 and K_2CO_3 .

g Symbol for the value of the *acceleration of free fall*.

gadolinium Gd. Element. A.W. 157.25. At. No. 64. R.d. 7.948, m.p. 1312°C. See *lanthanides*.

gain An increase in electronic signal power; usually expressed as the ratio of the output power (for example, of an *amplifier*) to the input power in *decibels*.

galactose $\text{CH}_2\text{OH}(\text{CHOH})_4\text{CHO}$. A *hexose sugar*, m.p. 166°C.; it is a constituent of *lactose* and certain plant *polysaccharides*.

galaxies Extra-galactic nebulae. The *stars* of the *Universe* are not evenly distributed throughout *space*, but are collected by gravitational attraction (see *gravitation*) into some 10^9 giant clusters called galaxies. Each galaxy contains about 10^{11} stars. The *Sun* is one of such a number of stars in our own *Galaxy* (the *Milky Way*), which is itself a member of a *local group of galaxies*. (See also *expansion of the Universe*.) The galaxies are separated from each other by enormous distances, the nearest galaxy to the *Milky Way* being some 16×10^5 *light years* away. Galaxies are either elliptical or spiral shaped (see *spiral galaxies*); a very few however appear to have no regular shape.

Galaxy, the The *Milky Way*. A cluster of some 10^{11} *stars*, one of which is the *Sun*. The *Galaxy* is a flat disc-shaped spiral structure, approximately 10^5 *light-years* across, with a slight bulge at the centre. The *solar system* is situated quite close to the central plane of this disc at a distance of about three fifths of its radius from the centre.

galena Natural lead sulphide, PbS . A heavy crystalline *mineral* of metallic appearance; it is the principal *ore* of lead. Used as a *semiconductor* in *crystal rectifiers*.

Galilean telescope A type of refracting *telescope* invented by Galileo Galilei (1564-1642) but no longer used in *astronomy* although its principle is still used in opera glasses. It consists of a *bi-convex objective* of long *focal length* and a *bi-concave eye-piece* of short *focal length*, producing an erect image.

gallic acid See *trihydroxybenzoic acid*.

gallium Ga. Element. A.W. 69.72. At. No. 31. A silvery-white *metal*, r.d. 5.9, m.p. 29.78°C. *Compounds* are very rare; the metal is used in high-temperature *thermometers* and gallium arsenide is used as a *semiconductor*.

gallon Unit of volume or capacity. The British Imperial gallon is the volume occupied by ten pounds of *distilled water* under conditions precisely defined by the 1963 Weights and Measures Act. Equal to

4.546 09 cubic decimetres (*litres*). The U.S. gallon is 0.832 68 British gallons.

galvanic cell See *primary cell*.

galvanized iron Sheet iron coated with a layer of zinc to prevent *corrosion*, usually made by dipping the sheet metal into the molten zinc.

galvanometer An instrument for detecting, comparing, or measuring small *electric currents*, but not usually calibrated in *amperes*; it requires calibration when an actual current measurement is needed. Galvanometers usually depend upon the magnetic effect produced by an electric current. See *ammeter*; *ballistic galvanometer*.

gamboge A yellow substance obtained from the hardened gum-resin of the tree *Garcinia Hanburii*. Used as a *pigment* and for colouring varnishes.

gamete Germ cell. A reproduction cell, usually *haploid* and sexually differentiated. The female gamete (or *ovum*) unites with the male gamete (or *spermatozoon*) during *fertilization* to produce a *zygote*, which develops into a new individual.

gametocyte A cell that undergoes *meiosis* to form *gametes*.

gamma-iron An allotropic form (see *allotropy*) of iron, which is non-magnetic and exists between 900°C. and 1400°C. See *austenite*.

gamma rays Gamma radiation. γ -rays. *Electromagnetic radiation* of the same nature, but shorter *wavelength* than *X-rays* (10^{-10} – 10^{-13} metre). They are emitted by the *nuclei* of *radioactive atoms* during *decay*. Gamma rays are emitted in *quantized* units called *photons*.

gangue The useless stony minerals that occur with a metallic ore.

garnet A group of *minerals* of varying composition, mainly double *silicates* of calcium or aluminium with other *metals*. Several varieties are red in colour, and are used as *gems*.

gas A substance whose *physical state* (the gaseous state) is such that it always occupies the whole of the space in which it is contained. In a *perfect gas*, the atoms and molecules would move freely but in a real gas they are subject to small inter-molecular *forces* (*Van der Waals' forces*). See also *kinetic theory of gases*.

gas carbon Retort carbon. A hard deposit consisting of fairly pure carbon, found on the walls of the *retorts* used for the *destructive distillation* of coal in the manufacture of *coal-gas*. A good *conductor* of *electricity*, it is used for making carbon *electrodes*.

gas chromatography Gas-liquid chromatography. A very sensitive method of analysing the components of a complex *mixture* of *volatile* substances. See *chromatography*. The apparatus consists of a long narrow tube, packed with an inert support material of uniform particle size (e.g. *diatomaceous earth*) that has been coated with a non-volatile *liquid*, called the stationary phase, the whole tube and its contents being maintained in a thermostatically controlled oven. The sample to be analysed is carried through the

GAS CONSTANT

tube by an *inert gas* (e.g. argon) so that the progress through the tube of various components of the mixture is selectively interfered with by the stationary phase, some components passing through the tube more rapidly than others. A detector measures the electrical or thermal *conductivity*, or some other characteristic property, of the gas leaving the column, differences being recorded on a strip chart, which indicates peaks corresponding to the various components. The instrument is calibrated by analysing samples of known compositions.

gas constant R . In the *gas equation*, $pV = RT$, the gas constant, R , equals 8.314 34 joules per kelvin per mole or 1.9858 calories per degree celsius per mole.

gas-cooled reactor A *nuclear reactor* in which the *coolant* is a gas. In the Mark I, or *magnox* type, natural uranium *fuel* is used with a *graphite moderator*, the *fuel elements* being cased in magnox. The coolant used is *carbon dioxide* and the outlet *temperature* is about 350°C., the hot gas being used to raise *steam*. In the Mark II, or advanced gas-cooled reactor (A.G.R.), the moderator is also graphite and the coolant is carbon dioxide, but in this type the outlet temperature is much higher (about 600°C.) and the fuel is *ceramic uranium dioxide* in a *stainless steel* casing.

gaseous combination, law of See *Gay-Lussac's law*.

gas equation An equation connecting the *pressure* and *volume* of a quantity of gas with the *absolute temperature*. For one mole of a perfect gas, $pV = RT$, where p = pressure, V = volume, T = absolute temperature, and R = the *gas constant*.

gas laws Statements as to the *volume* changes of *gases* under the effect of alterations of *pressure* and *temperature*. *Boyle's law* states that at constant temperature the volume of a given mass of gas is inversely proportional to the pressure; i.e. $pV = \text{constant}$. *Charles' law* states that at constant pressure all gases expand by 1/273 of their volume at 0°C. for a rise in temperature of 1°C.; i.e. the volume of a given mass of gas at constant pressure is directly proportional to the *absolute temperature*. For 1 mole of gas, the two laws may be combined in the expression $pV = RT$ (see *gas equation*), where T is the absolute temperature. This gives the behaviour of a gas when both temperature and pressure are altered. The gas laws are not perfectly obeyed by ordinary gases, being strictly true only for the *perfect gas*. See *gas laws, deviations from*.

gas laws, deviations from Gases do not strictly obey the *gas laws*, but follow them more and more closely as the *pressure* of the gas is reduced. Various *equations* have been derived that attempt to give a better approximation to the behaviour of actual gases. The best known of these is *Van der Waals' equation*. See also *virial equation*.

gas mantle A structure composed of the *oxides* of thorium (99%) and cerium (1%), made by impregnating a combustible fabric with a *solution* of the *nitrate*s of the metals, and decomposing the *nitrate*s by heat.

gas maser A maser in which *microwave radiation* interacts with *gas molecules*.

gas mask Respirator. A device for protecting the face and breathing organs against poisonous 'gases'. (These include poisonous *smokes*, etc., used in chemical warfare.) The air is drawn through a layer of *activated carbon*, which adsorbs vapours, and also through a filter-pad, which retains solid particles of smokes. Such an arrangement is effective against war 'gases' and smokes, but not against gases of low *molecular weight* such as *carbon monoxide* or *coal-gas*.

gas oil Diesel oil. The oil left after *petrol* and *kerosene* have been distilled from crude *petroleum*. Used as a *fuel* for *diesel engines* and for carburetting *water gas*.

gasoline The name for *petrol* in the USA.

gas thermometer An apparatus for measuring *temperature* by the alteration in *pressure* produced by temperature changes in a *gas* kept at constant *volume*, or by the alteration in *volume* of a *gas* kept at constant *pressure*. For practical purposes, other more convenient forms of thermometer are used whenever possible. However, the gas thermometer, operated at low *pressure*, gives the only direct means of determining the *thermodynamic temperature*.

gas turbine An engine that converts the *chemical energy* of a *liquid fuel* into *mechanical energy* by *internal combustion*, the gaseous products of which are expanded through a *turbine*. Used as the power plant in aeroplanes (both turbo-propeller and turbo-jet driven), locomotives, and experimentally in motor-cars. Also used as an auxiliary power plant in electrical generating stations.

gate 1. A circuit with only one output, but which has more than one input and which can be activated by various combinations of input signals. 2. A signal that activates a circuit for a predetermined time or until another signal is received. 3. A device for selecting portions of a wave, either on a time or *amplitude* basis. 4. The electrode in a *field-effect transistor* that controls the flow of current through the channel.

gauss The c.g.s. system unit of *magnetic flux density*. If a *magnetic field* of 1 *oersted* intensity exists in a medium of unit *magnetic permeability*, e.g. air, then the induction will be 1 gauss. Equal to 1 *maxwell* per square centimeter or 10^{-4} *weber* per square *metre* (i.e. 1 *tesla*). Named after K. F. Gauss (1777-1855).

gaussmeter A *magnetometer* calibrated in *gauss*, for measuring *magnetic flux density*.

Gauss's law The total *electric flux* of a closed surface in an *electric field* is 4π times the *electric charge* within that surface.

GAY-LUSSAC'S LAW

Gay-Lussac's law of gaseous combination When gases combine, they do so in simple ratio by *volume* to each other, and to the gaseous product, measured under the same conditions of *temperature* and *pressure*. Explained by *Avogadro's law*. Named after Joseph Louis Gay-Lussac (1778-1850).

Gegenschein Counter glow. A faint elliptical patch of *light* in the sky that may be observed at night directly opposite the *Sun*, though it is rarely seen in Britain. It is caused by a reflection of sunlight by meteoric particles in *space*.

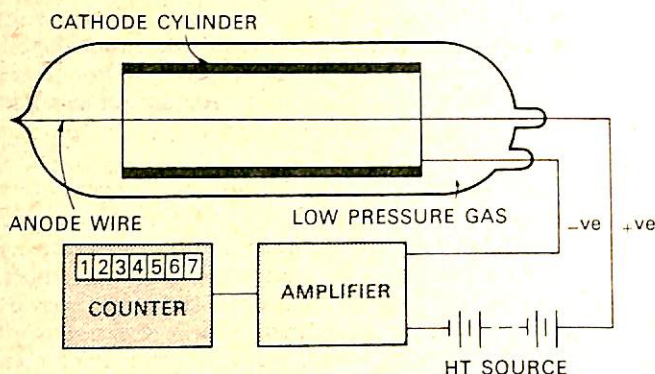


Figure 16.

Geiger counter Geiger-Muller counter. An instrument for the detection of *ionizing radiations* (chiefly *alpha*, *beta*, and *gamma rays*), capable of registering individual particles or *photons*. It consists normally of a fine wire *anode* surrounded by a *coaxial cylindrical metal cathode*, mounted in a glass envelope containing gas at low pressure. A large *potential difference*, usually about 1000 volts, is maintained between the anode and the cathode. The *ions* produced in the counter by an incoming ionizing particle are accelerated by the applied potential difference towards their appropriate *electrodes*, causing a momentary drop in the potential between the latter. This voltage *pulse* is then passed on to various *electronic* circuits by means of which it can, if desired, be made to work a counter. See Fig. 16. Named after Hans Geiger (1882-1947).

Geiger-Nuttall law The approximate empirical law that the range R of an *alpha particle* emitted by a radioactive substance is given by the relation: $\log \lambda = B \log R + A$, where λ is the *disintegration constant* of the substance and A and B are constants.

Geissler tube A tube for showing the luminous effects of a *discharge* of *electricity* through various rarefied *gases*. Consists of a sealed glass

tube containing platinum electrodes. Named after H. Geissler (1814-79).

gel A *colloidal solution* that has set to a jelly, the *viscosity* being so great that the solution has the *elasticity* of a *solid*. The formation of a gel is attributed to a mesh-like structure of the *disperse phase* or *colloid*, with the *dispersion medium* circulating through the mesh-work.

gelatin Gelatine. A complex *protein* formed by the *hydrolysis* of *collagen* in animal cartilages and bones, by boiling with water. Soluble in water, the *solution* has the property of setting to a jelly. Used in foods, *photography*, as an *adhesive*, textile size, and in a variety of other arts and industries.

gelation 1. The process of *freezing*. See also *regelation of ice*. 2. The formation of a *gel*.

gelignite An *explosive* consisting of a *mixture* of *nitroglycerin*, *cellulose nitrate*, *saltpetre* (*potassium nitrate*, KNO_3), and wood pulp.

gem See *vicinal*.

gene A hypothetical unit, comprising part of a *chromosome*, which controls an individual inherited characteristic of an *organism* and which is capable of *mutation* as a unit. (See also *cistron*.) The gene is regarded as being a particular molecular configuration of the *nucleic acids* (which partially constitute a chromosome) at a particular point on the length of a chromosome. There is considerable evidence to support the belief that genes function by controlling the manufacture of specific *proteins* (including *enzymes*) in *cells*. See *operon*; *genetic code*.

general theory of relativity See *relativity*, *theory of*.

generation time The average lapse of time between the creation of a *neutron* by *nuclear fission* and a subsequent fission produced by that neutron.

generator A machine for producing *electrical energy* from *mechanical energy*. See *dynamo*.

generatrix (math.) A point, line, or *plane* the movement of which produces a line, surface, or solid.

genetic code The code by which inherited characteristics are handed from generation to generation. The code is expressed by the molecular configuration of the *chromosomes* of *cells*. Chromosomes consist of *deoxyribonucleic acid* (DNA) and *protein*, the code-bearing material being the DNA. Four different nitrogenous bases (*adenine*, *cytosine*, *guanine*, and *thymine*) occur in the *nucleotides* of DNA, and it appears that the sequence of three of these bases constitutes a unit of the genetic code, in that each sequence of three bases codes for one of the twenty different *amino acids* that go to make up the *enzymes* that control the characteristics of a cell. Chromosomes, which almost always exist in the *nuclei* of cells,

GENETICS

transfer their coded information to the *cytoplasm* of these cells (where the enzyme proteins are assembled in units called *ribosomes*) by way of a 'messenger' nucleic acid (*ribonucleic acid*).

genetics The study of heredity, variation, development, and *evolution*.

genotype 1. The genetic constitution of an individual *organism* or of a well defined group of organisms. 2. A group of organisms that have the same genetic constitution. 3. A typical species of a genus. See also *phenotype*.

gentian violet A purple dye derived from *aniline*, used as an *indicator*, an *antiseptic*, and a *dye*.

geocentric Having the *Earth* as a centre; measured from the centre of the *Earth*.

geochemistry The study of the chemical composition of the *Earth's crust* and the changes that take place within it.

geodesic Pertaining to the *geometry* of curved surfaces. A 'geodesic line', also called a 'geodesic', is the shortest distance between two points on a curved surface.

geodesy Surveying on a scale that involves making allowance for the curvature of the *Earth*.

geological time scale Geological periods. A scale of time that serves as a reference for correlating various events in the history of the *Earth*; it has been built up by studying the various strata of rocks that comprise the *Earth's crust* with special reference to the *fossils* found in them. The time scale is divided into three main 'eras', based upon the general character of the life that they contain, each era being subdivided into 'periods'. The Table gives the names of these eras and periods, together with their approximate ages.

geology The scientific study of the *Earth's crust*.

geomagnetism The study of the *magnetic field* associated with the *Earth*. See *magnetism*, *terrestrial*.

geometrical progression A series of quantities in which each term is obtained by multiplying the preceding term by some constant factor, termed the 'common ratio'. E.g. 1, 3, 9, 27, 81..., each term being three times the preceding. For a series of n terms, having common ratio r and the first term a , the sum

$$S = a(r^n - 1)/(r - 1);$$

or, if r is less than 1, a more convenient expression is

$$S = a(1 - r^n)/(1 - r).$$

geometric mean The geometric *mean* of n positive numbers, a, b, c, \dots is $(abc\dots)^{1/n}$. E.g. the geometric mean of 3 and 12 is 6.

geometry The mathematical study of the properties and relations of lines, surfaces, and solids in space.

geophysics The study of the *Earth* and its *atmosphere* by physical

GEOLOGICAL TIME SCALE

<i>Era</i>		<i>Period</i>	<i>Time Scale</i> <i>millions of years</i>
CENOZOIC	QUATERNARY	Holocene	0.01
		Pleistocene (Glacial)	1
	TERTIARY	Pliocene	10
		Miocene	25
		Oligocene	40
		Eocene	60
		Paleocene	70
	MESOZOIC (SECONDARY)	Cretaceous	135
		Jurassic	180
		Triassic	225
PALAEOZOIC (PRIMARY)	Permian	270	
	Carboniferous	350	
	Devonian	400	
	Silurian	440	
	Ordovician	500	
	Cambrian	600	
PRE-CAMBRIAN		2000	

methods. This includes *seismology*, *meteorology*, *hydrology*, *terrestrial magnetism*, etc.

geraniol $C_{10}H_{17}OH$. A *liquid terpene alcohol*, b.p. $107^{\circ}C.$, present either free, or as an *ester*, in many *essential oils*.

germane Germanium tetrahydride. GeH_4 . A colourless gas. The germanium analogue of *methane*; the first member of a series of organogermanium compounds of the general formula Ge_nH_{2n+2} , corresponding to the *alkanes*.

germanium Ge. Element. A.W. 72.59. At. No. 32. A brittle white *metal*, r.d. 5.35, m.p. $937.4^{\circ}C$. *Compounds* are rare. Used in the *transistor*.

German silver An *alloy* of copper, zinc, and nickel in varying proportions, approximating to 5 parts Cu, 2 of Zn, and 2 of Ni.

germicide A substance capable of destroying *bacteria*.

getter Vacuum getter. A substance used for removing the last traces of air or other *gases* in attaining a high *vacuum*. E.g. magnesium metal is used in *thermionic valves*; after exhausting and sealing the valve a

- small amount of magnesium left in the valve is vaporized by *heat* and combines chemically with any remaining oxygen and nitrogen.
- GeV** Abbreviation for *giga electron-volt*, i.e. 10^9 electron-volts. In America this is usually written BeV where the 'B' represents the American *billion*.
- ghosts** (phys.) False lines appearing in a *line spectrum* due to imperfections in the ruling of the *diffraction grating* used.
- giant star** A *star* possessing high *luminosity*, low *density*, and a diameter 10 to 100 times that of the *Sun*.
- gibberellins** A group of *plant hormones*, that promote the growth of plant stems and fruit, and have other beneficial effects.
- gibbous** The shape of the *Moon* or a *planet* when it is more than half-phase, but less than full phase. (See *phases of the Moon*).
- Gibbs' function** See *free energy*. Named after Josiah Willard Gibbs (1839-1903).
- giga-** Prefix denoting a thousand million (10^9). Symbol G.
- gilbert** The c.g.s. unit of *magnetomotive force* in *electromagnetic units*. Equal to $10/4\pi$ *ampere-turns*. Named after William Gilbert (1540-1603).
- gilding** Covering with a thin layer of metallic gold, often by *electrolysis* (see *electroplating*).
- gill** A unit of capacity equal to one quarter of a *pint*.
- gillion** 10^9 , one thousand million.
- gilsonite** A pure form of *asphalt* that occurs in North America; used in *paints* and *varnishes*.
- glacial acetic acid** Pure *acetic acid*; *solid* crystalline acetic acid below its *freezing point* ($16.6^\circ\text{C}.$).
- glass** A hard brittle *amorphous mixture*, usually *transparent* or *translucent*, of the *silicates* of calcium, sodium, or other *metals*. Ordinary soda glass is made by melting together sand (*silica*), *sodium carbonate*, and *lime*. Glass for special purposes may contain lead, potassium, barium or other metals in place of the sodium, and *boric oxide* in place of the silica. See *crown glass*, *flint glass*.
- glass-ceramics** Materials that usually consist of lithium and magnesium *aluminosilicates*; they are chemically similar to glasses, but differ from glasses in consisting of very small crystals. They have high mechanical strength and very low thermal expansion, making them resistant to abrupt temperature changes. Used for heat-resisting ovenware, for radomes, and other purposes involving exposure to drastic conditions.
- glass fibre materials** Fibreglass*. Fine *glass fibres*, usually less than a quarter of a micrometre in diameter, that are woven into a cloth and impregnated with various *resins*. Owing to their high *tensile strength* and *corrosion* resistance these materials are used in small boat building and for some motor-car body parts.

glass transition The change, characteristic of many *rubbers* and other *polymers*, from a plastic or rubbery to a glassy or brittle state. The temperature region of this change (the glass temperature, glass-transition temperature, or second-order transition temperature) is designated T_g .

glass wool A material consisting of very fine *glass* threads, resembling cotton wool. Used for filtering and absorbing corrosive *liquids*.

Glauber's salt Crystalline *sodium sulphate*, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$. Named after J. R. Glauber (1604-68).

glaze A *vitreous* covering for pottery, chemically related to *glass*.

globular clusters Self-contained, approximately spherical clusters of about one hundred thousand *stars*; some hundred of these clusters are known to be distributed about the centre of the *Milky Way*, and although they appear to be outside the *Galaxy*, they are believed to be gravitationally associated with it.

globulins Groups of *proteins* soluble in dilute *solutions* of mineral *salts*, such as *sodium chloride*, NaCl , *magnesium sulphate*, MgSO_4 , etc. They occur in many animal and vegetable *tissues* and fluids; e.g. lactoglobulin in milk, serum globulin in *blood*, vegetable globulins in seeds. Globulins are the main proteins of *antibodies*.

glove box A metal box that provides protection to workers who have to manipulate *radioactive* materials or that enables the manipulation of substances requiring a dust-free, *sterile*, or *inert* atmosphere. Manipulation is carried out by means of gloves fitted to ports in the walls of the box.

glow discharge A silent discharge of electricity through a *gas* at low *pressure*, usually luminous. See *discharge in gases*.

glucinum See *beryllium*.

gluconic acid $\text{CH}_2\text{OH}(\text{CHOH})_4\text{COOH}$. A colourless *soluble* crystalline substance, m.p. 125°C ., obtained by the *oxidation* of *glucose*. Used for cleaning *metals*.

glucose Dextrose, grape-sugar. $\text{C}_6\text{H}_{12}\text{O}_6$. A colourless crystalline *soluble hexose sugar*. M.p. 146°C . It occurs in honey and sweet fruits. Other sugars and *carbohydrates* are converted into glucose in the human body before being utilized to provide *energy*. Glucose is an *optically active* substance, the naturally occurring sugar invariably being *dextrorotatory* (d-glucose). Commercially prepared from *starch* and other carbohydrates by *hydrolysis*; used in brewing, jam-making, confectionery, etc. The *laevorotatory* form (l-glucose) is rare and does not occur in nature.

glucosides See *glycosides*.

glue A general name for *adhesives*, particularly those made by extracting hides, bones, cartilages, etc., of animals with *water*.

gluon A hypothetical particle believed to be exchanged between *quarks* in order to bind them together.

GLUTAMATE

glutamate A salt or ester of *glutamic acid*.

glutamic acid A colourless crystalline *amino acid*, m.p. 206°C., used in the form of its sodium salt as a flavouring. See Appendix, Table 5.

glutamine A colourless *soluble amino acid*, m.p. 184–5°C. See Appendix, Table 5.

gluten Protein contained in wheat flour (8%–15%).

glycerides Esters of *glycerol* with *organic acids*. Animal and vegetable fats are mainly composed of triglycerides of *fatty acids*, such as *stearic*, *palmitic*, and *oleic*, a molecule of such a triglyceride being derived by the combination of one molecule of *glycerol* with three *fatty acid* molecules.

glycerin(e) See *glycerol*.

glycerol Glycerin(e). $\text{CH}_2\text{OH}.\text{CHOH}.\text{CH}_2\text{OH}$. A thick syrupy sweetish liquid triol soluble in water. B.p. 290°C. It occurs combined with *fatty acids* in fats and oils and is obtained by the saponification of fats in the manufacture of soap. Used in the manufacture of explosives (see *nitroglycerin*), plastics, in pharmacy, and as an anti-freeze.

glycerol monoacetate Acetin. $\text{CH}_3\text{COOC}_3\text{H}_5(\text{OH})_2$. A colourless viscous hygroscopic liquid, b.p. 158°C., used in the manufacture of explosives.

glyceryl The trivalent radical $-\text{CH}_2(\text{CH}-)\text{CH}_2-$, derived from *glycerol*.

glycine Aminoacetic acid, glycocoll. A colourless soluble crystalline *amino acid*, m.p. 232°C., used in organic synthesis. See Appendix, Table 5.

glycogen Animal starch. A complex carbohydrate formed from *glucose* in the liver and other organs of animals, serving as a sugar reserve.

glycol See *ethanediol*.

glycolipids Complex lipids that consist of compounds of *fatty acids* with carbohydrates and contain nitrogen but no *phosphoric acid*. Found in brain tissues.

glycols See *diols*.

glycolysis The conversion of *glucose* into *lactic acid* by a series of enzyme-catalyzed reactions that occur in living organisms.

glycoproteins Glucoproteins. Complex proteins that contain carbohydrates.

glycosides Ether-type compounds, derived from sugars and hydroxy compounds. If the latter component in a glycoside is a non-sugar, it is called an aglycone. Glycosides in which the sugar is *glucose* are called glucosides. Glycosides occur widely in plants.

glycyl The univalent radical $\text{NH}_2\text{CH}_2\text{CO}-$ (from *glycine*).

glyoxal Diformyl. $(\text{CHO})_2$. A yellow crystalline substance, m.p. 15°C., b.p. 51°C. Used in the manufacture of plastics, and in textile finishing.

glyptal resins Alkyd resins. A class of synthetic *resins* obtained by the reaction of *polyhydric alcohols* with *polybasic organic acids* or their *anhydrides*; e.g. *glycerol* and *phthalic anhydride*. Used chiefly for surface coatings.

gnotobiotics The study of germ-free life, especially in experimental conditions in which animals are inoculated with specific strains of *microorganisms*.

gold Au. Element. A.W. 196.967. At. No. 79. A bright yellow soft *metal* that is extremely malleable and ductile; m.p. 1064°C. , r.d. 19.32. Gold is not corroded by air, is unattacked by most acids, but dissolves in *aqua regia*. It occurs mainly as the free metal; most compounds are unstable and are easily reduced to gold. It is extracted from the ore by the *amalgamation process* and the *cyanide process*. *Alloys* with copper or silver, to give hardness, are used in coins, jewellery, and dentistry. Compounds are used in photography and medicine.

gold chloride See *auric chloride*.

gold leaf Gold is the most malleable of *metals*, and can be beaten into leaves 0.0001 mm thick (i.e. 254 000 thicknesses to the inch). The leaf has the appearance of metallic gold, but transmits green *light*; i.e. appears green when held up to the light.

gold-leaf electroscope See *electroscope*.

Goldschmidt process The preparation of *metals* from their *oxides* by *aluminothermic reduction*.

goniometer An instrument for the measurement of *angles* (of *crystals*).

gooch crucible A laboratory *filter* consisting of a shallow *porcelain* cup, the flat bottom of which is perforated with small holes over which a layer of *asbestos* fibres is placed.

governor A device for regulating the speed of an *engine* or machine, on the principle of negative *feedback*, so that its speed is kept constant under all conditions of loading. This is often achieved by controlling the *fuel* consumption, so that a rise in speed is arranged to reduce the fuel intake and a fall in speed to increase it.

gradient The degree of inclination of a slope, usually expressed as unit rise in height per number of units covered along the slope; i.e. the sine of the angle of rise (see *trigonometrical ratios*). Mathematically, the gradient is the ratio of the vertical distance to horizontal distance, i.e. the tangent of the angle. For small gradients the difference between the sine and the tangent is small.

graduation The marking that indicates the scale of an instrument, e.g. the stem of a *thermometer* is graduated in *degrees*.

Graham's Law of gaseous diffusion. The velocity of *diffusion* of a *gas* is inversely proportional to the square root of its *density*. Named after Thomas Graham (1805-69).

grain British unit of *weight*. $1/7000$ of a pound; 0.0648 g.

GRAM-ATOM

gram-atom The *atomic weight* of an *element* expressed in *grams*; e.g. 32 g of sulphur. See *mole*.

gram-equivalent The *equivalent weight* in *grams*. See *chemical equivalents*.

gram. gramme One of the *fundamental units* of measurement in the *c.g.s. system* of units. The unit of *mass*, defined as 1/1000 of the mass of the International Prototype *Kilogram*, a platinum-iridium standard preserved in Paris. Symbol g.

gram-ion The sum of the *atomic weights* of the *atoms* in an *ion* (see *electrolysis*) expressed in *grams*.

gram-molecular volume See *molar volume*.

gram-molecule Gram-molecular weight. The *molecular weight* of a *compound* expressed in *grams*; e.g. 18 g of water. See *mole*.

Gram's method A method of staining and classifying *bacteria* in which *gentian violet* is used to stain a bacterial smear. If the bacteria retain the violet dye, after washing with a *solution* of iodine and *potassium iodide* in water (Gram's solution) and counterstaining with *safranin*, they are said to be 'gram positive'. If they do not retain the dye they are said to be 'gram negative'. Named after Hans Gram (1853-1938).

gram weight A unit of *force*, the pull of the Earth on the *gram mass*; it varies slightly in different localities, depending on the value of *g*, the *acceleration of free fall* at the given place. Force expressed in grams weight = force in dynes divided by the appropriate value of *g* at the place under consideration. A force of 1 gram weight = approx. 981 dynes. 1 g = 0.0353 oz; 453.6 g = 1 lb.

granite Any of a class of heterogeneous igneous rocks, containing *quartz*, *feldspar*, and other *minerals*.

grape sugar See *glucose*.

graph A diagram, generally plotted between axes at right angles to each other, showing the relation of one *variable quantity* to another. E.g. the variation of rainfall with time, or the variation in the value of a *mathematical function* as different values are assigned to one of the variables in the function.

-graph A suffix applied to instruments that automatically record or write down observations; e.g. *barograph*.

graphite Blacklead, plumbago. A natural *allotropic form* of carbon, used for pencil leads, in electrical apparatus, and as a lubricant for heavy machinery. Also used as a *moderator* in *nuclear reactors*.

graphite-moderated reactor See *nuclear reactor*.

graticule 1. A scale, or network of fine wires, in the *eye-piece* of a *telescope* or *microscope*. 2. A network of parallel lines (longitudinal and latitudinal) on a map.

grating See *diffraction grating*.

gravimetric analysis A branch of *quantitative chemical analysis*. The amount of a substance present is determined by converting it, by a

suitable *chemical reaction*, into some other substance of known chemical composition, which can be readily isolated, purified, and weighed.

gravitation, Newton's law of Every particle in the *Universe* attracts every other particle with a *force* directly proportional to the product of the *masses* of the particles and inversely proportional to the square of the distance between them. Thus, the force of attraction between two masses m_1 and m_2 , separated by a distance of s , is given by

$$F = Gm_1m_2/s^2,$$

where G is the *gravitational constant*.

gravitational constant The fundamental constant that appears in Newton's Law of *gravitation*. It has the value $6.664 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$.

gravitational field The region in which one massive body (i.e. a body that possesses the attribute of *mass*) exerts a *force* of attraction on another massive body.

gravitational interaction The *interaction* between all massive particles. It is the weakest of all known interactions, being some 10^{40} times weaker than the *electromagnetic interaction*. Compare *strong interaction* and *weak interaction*.

gravitational mass See *inertial mass*.

graviton A hypothetical particle or *quantum* of gravitational *energy* (see *gravitation*), which has not yet been observed. If it exists it is expected to have zero *rest mass* and *charge*, and *spin* 2.

gravity The gravitational *force* (see *gravitation*) between the *Earth* (or other *planet* or *satellite*) and a body on its surface, or within its *gravitational field*. As gravity is proportional to the *mass* of the planet or satellite and inversely proportional to the square of the distance from its centre, the gravity on a planet or satellite in terms of the Earth's gravity is given by

$$(d_p/d_e)^2/M_p,$$

where M_p is the mass of the planet in Earth masses, and d_p and d_e are the diameters of the planet and Earth respectively. Substituting the relevant figures from Table 4 of the Appendix, will show that gravity on the surface of the *Moon* is 1/6 that on the surface of the Earth.

Gravity is responsible for the *weight* of a body; the weight of a body is the gravitational force of attraction that the Earth exerts on that body. It is equal to the mass of the body multiplied by the *acceleration of free fall*. Gravity causes bodies to fall to Earth with a uniform acceleration, but the magnitude of the acceleration of free fall varies with geographical location and altitude. Gravity is reduced to a very small extent by the *centrifugal force* caused by the

GRAY

Earth's rotation (for an object at rest on its surface). In order to stay in *orbit* round the Earth (or other planet or satellite), an orbiting body has to achieve a *velocity* that will produce a centrifugal force that exactly balances the force of gravity.

gray The derived *SI unit* of absorbed dose of ionizing radiation. The energy in *joules* absorbed by one *kilogram* of irradiated material. Symbol Gy.

grease A semi-solid lubricant composed of emulsified *petroleum* oils and *soluble hydrocarbon soaps*.

great circle A circle obtained by cutting a *sphere* by a *plane* passing through the centre. E.g. regarding the Earth as a sphere, the *Equator* is a great circle, as are all the *meridians* of longitude. On the Earth's surface, an apparent straight line joining any two points is an arc of a great circle, i.e. a *geodesic*.

Greek fire A mixture of materials that caught fire when wetted; used by the ancient Greeks in naval warfare. Probably composed of sulphur, *naphtha*, and *calcium oxide* or similar materials.

greenhouse effect 1. The effect produced inside a greenhouse: ultraviolet radiation is admitted to the greenhouse through its glass roof and is absorbed by the contents. The infrared radiation emitted by the contents cannot escape through the glass and the temperature of the interior rises. 2. A similar effect that applies to the whole Earth. Shortwave solar radiation passes through the atmosphere but atmospheric carbon dioxide absorbs the long-wave radiation emitted by the Earth. Thus solar energy is trapped by the Earth's atmosphere.

greenockite See *cadmium sulphide*.

green vitriol Copperas. *Ferrous sulphate crystals*, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$.

GREGORIAN TELESCOPE

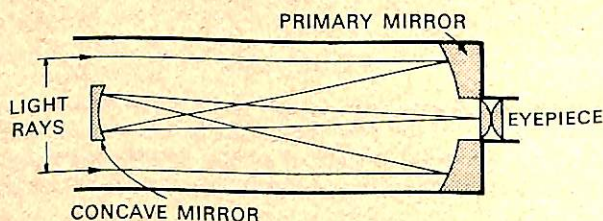


Figure 17.

Gregorian telescope A form of astronomical reflecting *telescope* similar to a *Cassegranian telescope* in that a hole in the centre of the parabolic *primary mirror* allows *light* to pass to the *eye-piece*, but in the Gregorian telescope the secondary mirror is *concave*

rather than *convex*. Although this type of telescope gives an erect image it is not now widely used as it is difficult to adjust. Named after James Gregory (1638-75). See Fig. 17.

grid 1. See *control grid*. **2.** A system of *high tension* cables (overhead or underground) by which electrical power is distributed throughout a country. **3.** A network of horizontal and vertical lines superimposed on a map to enable references to be given.

grid bias A fixed *voltage* applied between the *cathode* and the *control grid* of a *thermionic valve*, which determines its operating conditions.

Grignard reagents *Alkylmagnesium halides*, prepared by the action of magnesium metal on alkyl halides in *ether* solution; e.g. C_2H_5MgI . Used in *organic synthesis*. Named after François A. V. Grignard (1871-1935).

ground state The most stable *energy* state of a *nucleus*, *atom*, or *molecule*. The normal state of an atom when its circum-nuclear *electrons* move in *orbits* such that the energy of the atom is a minimum. See *atom*, *structure of*.

ground waves Direct waves. *Electromagnetic radiations* of *radio frequencies* that travel more or less directly from transmitting *aerial* to receiving *aerial*, that is without reflection from the *ionosphere*. See *sky waves*.

group 1. The set of *elements* that have similar chemical properties and constitute a vertical column in the *periodic table*. **2.** A number of covalently bonded atoms that form part of a *compound* and have characteristic properties. *Ethanol*, for example, consists of the *ethyl group* (C_2H_5-) and the *hydroxyl group* ($-OH$).

Grüneisen's law The ratio of the coefficient of *expansion* of a *metal* to its *specific heat capacity* at constant pressure is a constant at all *temperatures*.

guaiacol *o*-methoxyphenol. $CH_3OC_6H_4OH$. A yellowish crystalline substance, m.p. $28.6^\circ C.$, b.p. $205^\circ C.$, used in medicine as a local *anaesthetic*.

guanidine $HN:C(NH_2)_2$. A strongly *basic*, *water soluble*, crystalline *organic compound*, used in the manufacture of *plastics*, *explosives*, and *rubber accelerators*.

guanine 2-aminohypoxanthine. $C_5H_5N_5O$. A colourless *insoluble* crystalline substance; one of the four nitrogenous bases occurring in the *nucleotides* of *nucleic acids*, which play a part in the formulation of the *genetic code*.

guano Large deposits formed from the excrement and bodies of seabirds. They are found on islands off the coast of Peru. Very rich in nitrogen and phosphorus *compounds*, they provide a valuable *fertilizer*.

guided missile A missile (usually *rocket* propelled) whose flight path can be controlled during flight either by *radio* signals from an

GUM ARABIC

external source or by internal homing devices (pre-set or self-actuating). See *beam riding*, *command guidance*, *field guidance*, *homing guidance*, *inertial guidance*, *terrestrial guidance*.

gum arabic Gum Acacia. A *water soluble*, yellowish gum obtained from certain varieties of acacia. Used in food and pharmaceutical products and as an *adhesive*.

gums A large class of substances of vegetable origin, which are usually exuded from plants.

gun-cotton *Cellulose nitrate*, nitrocellulose. A powerful *explosive* formed by the action of *nitric acid* on *cellulose*.

gun-metal A variety of *bronze* containing about 90% copper, 8%-10% tin, and up to 4% zinc.

gunpowder A *mixture* of *potassium nitrate*, KNO_3 , powdered *charcoal*, and *sulphur*. When ignited, a number of *chemical reactions* take place, evolving *gases*, thus producing an *explosion* in a confined space.

gutta-percha A material very similar to *rubber*, obtained from the *latex* of certain Malayan trees; chemically, it consists of the *trans-form* of *polyisoprene*. A *horny substance* at ordinary temperatures; it is *thermoplastic* and at about 70°C . resembles *unvulcanized rubber*. Used for golf ball covers.

gypsum Natural *hydrated calcium sulphate*, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, that loses three quarters of its *water of crystallization* when heated to 120°C ., becoming *Plaster of Paris*.

gyration Motion round a fixed *axis* or *centre*.

gyro-compass Gyroscopic compass. A compass that does not make use of *magnetism*, and is therefore not affected by magnetic storms, etc.; it consists of a *universally-mounted spinning wheel* that has a rigidity of direction of axis and plane of rotation relative to space; the rotation being electrically maintained. See *gyroscope*.

gyromagnetic ratio The ratio of the *magnetic moment* of an *atom* or *nucleus* to its *angular momentum*.

gyroscope A spinning wheel mounted in such a way that it is free to rotate about any axis; i.e. 'universally mounted'. Such a wheel has two properties upon which applications of the gyroscope depend—namely, 1. Rigidity in space (gyroscopic inertia); the support of the wheel may be turned in any direction without altering the direction of the wheel relative to space. 2. Precession. When a gyroscope is subjected to a *force* tending to alter the direction of its axis, the wheel will turn about an axis at right angles to the axis about which the force was applied.

H

Haber process Haber-Bosch process. An industrial process for the preparation of *ammonia*, especially for use in *fertilizers*, from atmospheric nitrogen. A heated mixture of nitrogen and hydrogen is passed over a *catalyst* under pressure; the gases combine to form ammonia gas according to the equation $N_2 + 3H_2 = 2NH_3$. It was originally devised by Fritz Haber (1868-1934) and adapted for industrial production by Carl Bosch (1874-1940) in combination with his process for producing the necessary hydrogen (see *Bosch process*).

hadron Any *elementary particle* that can take part in a *strong interaction*. Hadrons include the *baryons* and *mesons* as well as the recently discovered *psi particle*. Hadrons are believed not to be truly elementary but to consist of *quarks* in different arrangements.

haematite Natural *ferric oxide*, Fe_2O_3 . A valuable ore of iron.

haematology The study of *blood*, its constituents, and the diseases connected with it.

haemocyte A *blood cell*.

haemoglobin Red colouring matter (respiratory pigment) present in the red *blood cells*; consists of a *protein*, *globin*, combined with a *prosthetic group*, *haem*, the latter being a highly complex *organic compound* containing iron, nitrogen, carbon, hydrogen, and oxygen. It serves to carry oxygen, which is breathed in, round the body in the form of an easily decomposed compound, *oxy-haemoglobin*.

hafnium Cesium. Hf. Element. A.W. 178.49. At. No. 72. A rare *metal*, r.d. 13.3, m.p. 2150°C. Used in the manufacture of tungsten *filaments* and as a *neutron absorber* in *nuclear reactors*.

hair salt Natural *aluminium sulphate*, $Al_2(SO_4)_3 \cdot 18H_2O$.

half cell Half of an *electrolytic cell*, consisting of an electrode dipping into an *electrolyte*. The *electrode potential* of such a system is measured by comparison with a *hydrogen electrode*, which is assigned an electrode potential of zero.

half-life Half-value period. The time taken for the *activity* of a *radioactive isotope* to *decay* to half of its original value, that is for half of the *atoms* present to disintegrate. Half-lives vary from isotope to isotope, some being less than a millionth of a second and some more than a million years. Symbol $T_{\frac{1}{2}}$.

half-period zones The division of a *wave front* into elements of area or zones such that secondary wavelets (see *Huygens' construction*) reaching a given point ahead of the wave from adjacent zones differ in *phase* by half a period, or π . This construction is used in theoretical investigations of *Fresnel diffraction* in simple cases.

HALF-THICKNESS

half-thickness Half value layer. The thickness of a specified material that, when introduced into the path of a given beam of *radiation*, reduces its intensity to one half of its original value.

half-wave plate A plate of double refracting material (see *double refraction*) cut parallel to the *optic axis* and of such a thickness that a *phase difference* of π or 180° is introduced between the *ordinary ray* and the extraordinary ray for *light* of a particular *wavelength* (usually sodium light). The half-wave plate is chiefly used to alter the plane of vibration of plane-polarized light. See *polarization of light*.

halide A *binary compound* of one of the *halogen elements* (fluorine, chlorine, bromine, or iodine); a *salt* of the *hydride* of one of these elements.

Hall effect If an *electric current* flows in a wire placed in a strong transverse *magnetic field*, a *potential difference* is developed across the wire, at right angles to both the magnetic field and the wire. Named after Edwin H. Hall (1855-1938).

Halley's comet A bright *comet* that takes about 76 years to orbit the Sun; last seen in 1910 it is next due to be visible in 1986. Named after Edmund Halley (1656-1742) who first calculated its orbit.

Hall mobility Drift mobility. The mobility of *carriers* in a *semiconductor*; numerically, it is the *velocity* of the carriers under the influence of an *electric field* of 1 volt per metre.

halo A luminous ring sometimes observed surrounding the Sun or the Moon. Caused by the *refraction* of *light* by *ice crystals* in the *atmosphere*.

halogenation The introduction of *halogen atoms* into a *compound* by addition or substitution.

halogens The four *elements* fluorine, chlorine, bromine, and iodine, having closely related and graded properties. (Astatine is also a member of the halogen group, but it has no stable *isotopes*.)

haploid Having a set of single (unpaired) *chromosomes*; e.g. *gametes*.

hardening of fats The conversion of *liquid fats* (oils) consisting mainly of *triolein* into hard fats by the action of hydrogen in the presence of a *catalyst*. See *hydrogenation of oils*.

hard radiation See *soft radiation*.

hardware See *software*.

hard water Water that does not form an immediate lather with *soap*, owing to the presence of calcium, magnesium, and iron *compounds* dissolved in the water. The addition of soap produces an *insoluble* scum consisting of *salts* of these *metals* with the *fatty acids* of the soap, until no more is left in *solution*. Removal of these salts from solution renders the water soft. Hardness is divided into two types: 1. Temporary hardness, due to hydrogen carbonates (*bicarbonates*) of the metals. These enter the water by the passage of the water, containing dissolved *carbon dioxide*, over *solid carbonates* (*chalk*

or *limestone* deposits, etc.). Such hardness is removed by *boiling*, the soluble bicarbonates being decomposed into the insoluble carbonates (see *fur in kettles*), carbon dioxide and water. 2. Permanent hardness, due to *sulphates* of the metals. This is destroyed by the addition of washing-soda, *sodium carbonate*, which precipitates the insoluble carbonates. All hardness may be destroyed by the use of *zeolites*.

harmonic motion See *simple harmonic motion*.

harmonic series (math.) A *series* in which the *reciprocals* of the terms are in *arithmetical progression*. E.g. $1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} \dots$

harmonics of a wave motion Waves superimposed on a fundamental wave, having a *frequency* that is a whole multiple of the fundamental frequency. The second harmonic has a frequency twice that of the fundamental, the third harmonic three times, and so on.

hartree Atomic unit of energy. A unit of energy equal to e^2/a_0 , where e is the charge of an *electron* and a_0 is the atomic unit of length. It is equal to 4.85×10^{-18} joule or 27.2 eV.

Hartstorn, spirits of A *solution of ammonia* in water.

health physics The branch of *physics* that deals with the effects of *ionizing radiation* on living *organisms*, with particular reference to the protection of humans from the ill-effects caused thereby.

heat *Energy* possessed by a substance in the form of *kinetic energy* of atomic or molecular translation, rotation, or vibration. The heat contained by a body is the product of its *mass*, its *temperature*, and its *specific heat capacity*; it is expressed in *joules* (*SI units*), *calories* (*c.g.s. units*) or *British Thermal Units* (*f.p.s. units*). Heat is transmitted by *conduction*, *convection*, and *radiation*. The chief observable physical effects of a change in the heat content of a body may include rise in temperature; change of state from *solid* to *liquid* (melting), *solid* to *gas* (sublimation) and *liquid* to *gas* (*evaporation* and *boiling*); *expansion*; and electrical effects such as the *Peltier* and *Seebeck effects*.

heat capacity C . When the *temperature* of a system is increased by an amount dT as a consequence of the addition of a small quantity of *heat* dQ , the quantity dQ/dT is called the heat capacity. In practice, it is the heat in *joules* required to raise the temperature of a body or system by 1 K. See *specific heat capacity* and *molar heat capacity*.

heat death of the universe The second law of thermodynamics (see *thermodynamics*, *laws of*) can be interpreted to mean that the *entropy* of a closed system tends towards a maximum and that its available *energy* tends towards a minimum. It has been held that the *Universe* constitutes a thermodynamically closed system, and if this were true it would mean that a time must finally come when the *Universe* 'unwinds' itself, no energy being available for use. This state is referred to as the 'heat death of the Universe'. It is by no

HEAT EXCHANGER

means certain, however, that the Universe can be considered as a closed system in this sense.

heat exchanger Any device that transfers *heat* from one *fluid* to another without allowing the fluids to come into contact with each other. The simplest type consists of a cylinder within which a coiled tube is mounted. One fluid passes through the coiled tube in one direction, while the other fluid passes through the cylinder, outside the tube, in the other direction.

heat of combustion The amount of *heat* evolved by 1 *mole* of a substance when it is burned in oxygen.

heat of formation The quantity of *heat* (usually expressed in *joules* or *calories*) liberated or absorbed when 1 *mole* of a *compound* is formed from its *elements* in their normal state. The heat of formation of elements is, for the purpose of thermochemical calculations, taken as zero. See *Hess's law*.

heat of neutralization The quantity of *heat* evolved when 1 *mole* of an *acid* or *base* is exactly neutralized. For all strong acids or bases, its value is approximately 57 500 *joules* (13 700 *calories*).

heat of reaction The quantity of *heat* given out or absorbed in a *chemical reaction*, usually per *mole* of reacting substances. See *Hess's law*.

heat of solution The quantity of *heat* evolved or absorbed when 1 *mole* of a substance is dissolved in a large volume of *water*.

heat pump A machine for extracting *heat* from a *fluid* that is at a slightly higher *temperature* than its surroundings. For example, the rivers flowing through industrial towns are often slightly warmer than the ambient temperature as a result of the disposal of hot effluents in them. A heat pump can be used to raise the temperature of this 'low temperature heat', so that it can be usefully employed.

heat radiation See *infrared radiation*.

heat shield The shielding surface or structure that protects a *spacecraft* from excessive heating on re-entering the *Earth's* atmosphere. (See *re-entry*.)

Heaviside-Kennelly layer A region of the *ionosphere*, between 90 and 150 kilometres above the surface of the *Earth* (for more recent designation of layers see *ionosphere*) that reflects *electromagnetic radiation* of *radio frequencies*. Inter-continental radio transmission, round the curved surface of the *Earth*, is possible because of the reflection of *sky-waves* by the Heaviside-Kennelly layer. Named after Oliver Heaviside (1850-1925) and Arthur Kennelly (1861-1939).

heavy hydrogen See *deuterium*.

heavy spar See *barytes*.

heavy water Deuterium oxide. D_2O . *Water* in which the hydrogen is replaced by *deuterium*. Present in natural water to the extent of about 1 part in 5000. Pure heavy water has r.d. 1.1, f.p. $3.82^\circ C.$, b.p.

- 101.42°C. The term is also used when referring to water that contains appreciably more D_2O or HDO than natural water. Heavy water is used as a *moderator* in some *nuclear reactors*.
- hectare** Metric unit of area; 10 000 square *metres*, 2.471 05 *acres*.
- hecto-** Prefix denoting one hundred times. Symbol h.
- Heisenberg's uncertainty principle** See *uncertainty principle*.
- heliocentric** Having the *Sun* as a centre; measured from the centre of the *Sun*.
- helium** He. Element. A.W. 4.0026. At. No. 2. An *inert gas* that occurs in certain *natural gases* in the U.S.A., occluded in *radioactive ores* (e.g. *monazite*, *pitchblende*), and in the *atmosphere* (1 part in 200 000). Non-inflammable and very light, it is valuable for filling airships and balloons.
- helix** A spiral. Many large natural *molecules* (e.g. *proteins* and *nucleic acids*) are helical in shape.
- Helmholtz free energy** See *free energy*. Named after Hermann von Helmholtz (1821-94).
- hemicelluloses** *Polysaccharides* (mainly *pentosans*) that occur in cell walls of plants associated with *cellulose* and *lignin*.
- hemihydrate** A *compound* that has one molecule of *water of crystallization* for every two molecules of the compound. *Plaster of Paris*, $2CaSO_4 \cdot H_2O$ or $CaSO_4 \cdot \frac{1}{2}H_2O$, is sometimes called hemihydrate plaster.
- hemimorphite** Natural *zinc silicate*, $2ZnO \cdot SiO_2 \cdot H_2O$.
- henry** The derived *SI unit* of self- and mutual inductance (see *self-induction*; *mutual induction*). An inductance in a closed *circuit* such that a rate of change of current of 1 *ampere* per second produces an induced *E.M.F.* of 1 *volt*. Symbol H. Named after Joseph Henry (1797-1878).
- Henry's law** The *mass* of a gas dissolved by a definite *volume* of *liquid* at constant *temperature* is directly proportional to the *pressure*. From this it follows that the volume of a gas absorbed by a given volume of liquid at constant *temperature* is independent of the *pressure*. The law holds only for sparingly *soluble* gases at low *pressures*. Named after William Henry (1774-1836).
- heparin** A complex *organic acid* related to the *polysaccharides* but containing sulphur and nitrogen, which prevents the clotting of *blood* by interfering with the formation, and action, of *thrombin*. Used as an anticoagulant.
- hepta-** Prefix meaning seven.
- heptane** C_7H_{16} . The seventh member of the *alkane* series. It is found in *petroleum* and has nine known isomers (see *isomerism*); *n*-heptane has b.p. 98.4°C. and r.d. 0.68.
- heptavalent** Septivalent. Having a *valence* of seven.
- herbicides** Substances that kill plants or inhibit their growth. Selective

HEROULT FURNACE

herbicides affect only particular plant types, making it possible to attack weeds growing among cultivated plants.

Héroult furnace See *electric-arc furnace*.

Herschelian telescope A form of astronomical reflecting *telescope* in which the primary mirror is *concave* and is set at an angle to the incoming light, enabling the incoming light to be reflected directly into the *eyepiece*.

hertz The derived *SI unit* of *frequency* defined as the frequency of a periodic phenomenon of which the periodic time is one *second*; equal to 1 cycle per second. Symbol Hz. 1 kilohertz (kHz) = 10^3 cycles per second; 1 megahertz (MHz) = 10^6 cycles per second. Named after Heinrich Hertz (1857-94).

hertzian waves Wireless waves, *radio waves*. *Electromagnetic radiation* covering a range of *frequency* from above 3×10^{10} hertz, corresponding to the shortest *radar waves* of 1 cm, to below 1.5×10^5 hertz, corresponding to long radio waves of 2000 metres.

Hertzprung-Russell diagram H-R diagram. A method of correlating data concerning *stars*. It consists of a *graph* in which the absolute *luminosity* of a star is plotted against its spectral type (obtained by examining the *spectra* of stars and arranging them in a sequence that reflects increasing *temperature*). This graph is thus essentially a plot of total *energy* output against surface temperature. The outstanding feature of this type of diagram is that most stars are concentrated in a narrow band running across the diagram: the stars at the upper end of the band are hot, bright, and bluish-white, while those at the lower end are cooler, dimmer, and reddish in colour. This band is called the 'main sequence' and stars that fall on it are called main sequence stars. It is mainly from H-R diagrams that the theory of *stellar evolution* has been derived. Named after Ejnar Hertzprung (1873-1969) and Henry N. Russell (1897-1957).

Hess's law If a *chemical reaction* is carried out in stages, the algebraic sum of the amounts of *heat* evolved in the separate stages is equal to the total amount of heat evolved when the reaction occurs directly; a consequence of the law of *conservation of energy* as applied to *thermochemistry*. Named after G. H. Hess (1802-50).

hetero- Prefix denoting other, different.

heterocyclic compounds *Organic compounds* containing a ring structure of *atoms* in the *molecule*, the ring including atoms of *elements* other than carbon. E.g. pyridine, C_5H_5N , having a *molecule* consisting of 5 carbon atoms and 1 nitrogen atom in a closed ring, with a hydrogen atom attached to each carbon atom.

heterodyne A beat effect (see *beats*) produced by superimposing two waves of different *frequency*. Used extensively in *radio* receivers in which the received wave is combined with a wave (of slightly different frequency to the *carrier wave*) generated within the receiver. The two combining waves produce an *intermediate*

frequency, which is amplified and then *demodulated*. See *superheterodyne*.

heterogeneous Not of a uniform composition; showing different properties in different portions.

heterolytic fission The breaking of a chemical bond so that charged ions are formed, e.g. $\text{HCl} = \text{H}^+ + \text{Cl}^-$. Compare *homolytic fission*.

heteropolar bond An electrovalent bond. See *valence*, *electronic theory of*.

heuristic Denoting the method of solving mathematical problems for which no *algorithm* exists; it involves the narrowing down of the field of search for a solution by inductive reasoning from past experience of similar problems.

Heusler's alloys *Alloys* containing neither iron, nickel, nor cobalt that exhibit strong *ferromagnetism*. They are composed of copper, manganese, and aluminium. Named after Conrad Heusler.

hexa- Prefix denoting six; six times.

hexadecane Cetane. $\text{C}_{16}\text{H}_{34}$. A colourless *liquid alkane*, m.p. 18°C ., b.p. 287°C . Used as a *solvent* and in the determination of *cetane numbers*.

hexadecanol Cetyl alcohol. $\text{C}_{16}\text{H}_{33}\text{OH}$. A white crystalline *insoluble solid*, m.p. 50°C ., used in cosmetics and in pharmaceutical products.

hexamine Hexamethylenetetramine, urotropine. $(\text{CH}_2)_6\text{N}_4$. A white crystalline substance obtained by the *condensation of ammonia* with *formaldehyde*. Used in medicine, in the manufacture of *vulcanized rubber*, and in the manufacture of *cyclonite*.

hexane C_6H_{14} . The sixth member of the alkane series. It is found in *petroleum* and has five known isomers (see *isomerism*); *n*-hexane has b.p. 69°C . and r.d. 0.66.

hexanoic acid Caproic acid. $\text{CH}_3(\text{CH}_2)_4\text{COOH}$. A colourless oily liquid with an unpleasant smell, b.p. 205°C . Its esters, e.g. ethyl caproate, are used in artificial flavourings.

hexavalent Sexivalent. Having a *valence* of six.

hexogen See *cyclonite*.

hexosans *Polysaccharides* that yield *hexoses* on *hydrolysis*.

hexose A *monosaccharide* whose *molecule* contains six carbon atoms, e.g. the *sugars* *glucose*, *fructose*, and *galactose*.

hexyl group Any of the five *isomeric univalent radicals* $\text{C}_6\text{H}_{13}-$.

hexylresorcinol $\text{C}_6\text{H}_{13}\text{C}_6\text{H}_3(\text{OH})_2$. A yellow crystalline *solid*, m.p. 60°C ., used as an *antiseptic* and in medicine.

high fidelity See *fidelity*.

high frequency HF. *Radio frequencies* between 3000 and 30 000 kilohertz. See Appendix, Table 10.

high-frequency welding Radio-frequency welding. A method of welding *thermoplastic* materials in which the *heat* required to fuse the

HIGH-SPEED STEEL

surfaces together is generated by the application of *radio frequency electromagnetic radiation*.

high-speed steel A very hard *steel* containing 12%–22% tungsten, with chromium, vanadium, molybdenum, and small amounts of other *elements*; used for tools which remain hard even at red heat.

high tension *High voltage*.

histamine $C_5H_7N_2(CH_2)_2NH_2$. A white crystalline substance, m.p. $86^\circ C.$, that occurs in animal *tissues* when they are injured and as part of the allergic reaction, causing dilation of blood vessels; it also stimulates gastric secretion of *hydrochloric acid*.

histidine A crystalline *soluble amino acid*, which occurs in fish and from which *histamine* is manufactured. See Appendix, Table 5.

histogram A type of graphical representation, used in *statistics*, in which frequency distributions are illustrated by rectangles.

histology The study of the structure of the *tissues* and organs of living creatures.

hodoscope An apparatus for tracing the path of a charged particle (usually a *cosmic-ray* particle).

hole The absence of an *electron* in the *valence* structure (see *energy bonds*) of a crystalline *semiconductor*. The filling of these vacancies by electrons, which thereby creates new holes, gives rise to 'hole conduction'. A hole may, therefore, be regarded as a mobile vacancy with a positive *electronic charge* and a positive *mass*; it is thus mathematically equivalent to a *positron*.

holmium Ho. Element. A.W. 164.93. At. No. 67. R.d. 8.803, m.p. $1461^\circ C$. See *lanthanides*.

holo- Prefix denoting whole-; e.g. *holohedral crystal*, a crystal having the full number of faces for perfect symmetry.

holocellulose All the *carbohydrate* components of a *cellulose* raw material.

hologram The intermediate photographic record that contains the information for reproducing a three-dimensional image by *holography*.

holography A method of reproducing three-dimensional images without *cameras* or *lenses* using photographic *film* and *coherent light*. A beam of coherent light from a *laser* is split in two by a semi-transparent mirror, so that one beam (the signal beam) can be *diffracted* by the object to be reproduced onto a photographic film or plate. The other beam (the reference beam) falls directly onto the film or plate (see Fig. 18a). The two beams form *interference* patterns on the plate thus forming the *hologram*. The fine speckled pattern on the plate contains information characteristic of the wave *fronts* themselves, rather than of the light intensities as in normal *photography*. To reproduce the image the hologram is illuminated by coherent light (usually of the same *wavelength* as the original beam). The hologram acts as a *diffraction grating* and produces two

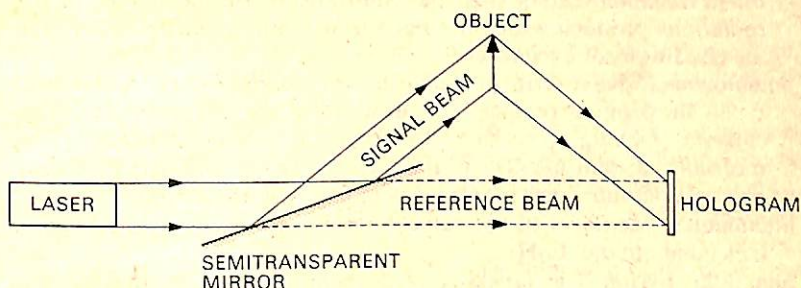


Figure 18a.

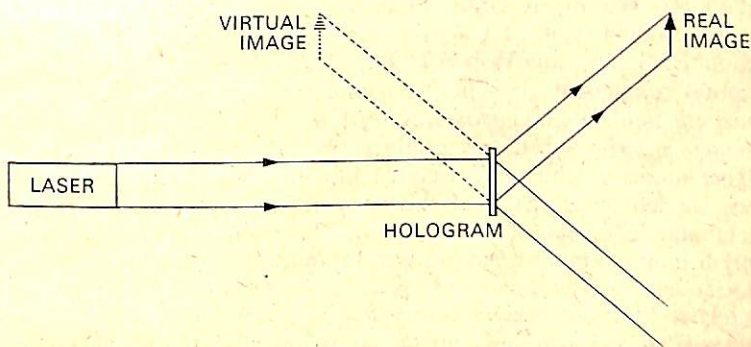


Figure 18b.

sets of diffracted waves, which form equal angles with the plate (see Fig. 18b). One set of waves forms a *real image* on a screen or photographic plate, while the other forms a three-dimensional *virtual image*.

homeomorphous Having the same crystalline form but different chemical composition.

homing guidance A method of missile or *rocket* guidance in which the missile contains equipment enabling it to detect and steer itself onto its target.

homo- Prefix denoting same-; e.g. *homogeneous*.

homocyclic compounds *Organic compounds* the *molecules* of which contain a ring structure of *atoms* of the same kind (usually carbon). E.g. *benzene*, C_6H_6 .

homogeneous Of uniform composition throughout.

homologous pair In *spectrographic analysis* an homologous pair consists of the particular spectral line (see *line spectrum*) utilized in

HOMOLOGOUS SERIES

the determination of the *concentration* of an *element* and an *internal standard line*, such that the ratio of the intensities of the *radiations* producing the lines remains unchanged with variations in the conditions of *excitation*.

homologous series A series of chemical *compounds* of uniform chemical type, showing a regular gradation in physical properties, and capable of being represented by a general *molecular formula*, the *molecule* of each member of the series differing from the preceding one by a definite constant group of *atoms*. E.g. the *alkanes*.

homologues Members of the same *homologous series*; e.g. *methane*, CH_4 , and *ethane*, C_2H_6 .

homolytic fission The breaking of a chemical bond so that neutral atoms or radicals are formed. Compare *heterolytic fission*.

homopolar bond A covalent bond. See *valence*, *electronic theory of*.

Hooke's law Within the *elastic limit*, a *strain* is proportional to the *stress* producing it. 'Ut tensio, sic vis.' See *elasticity*, *elastic modulus*. Named after Robert Hooke (1635-1703).

horizontal component B_0 . The horizontal component of the Earth's *magnetic field*. See *magnetism*, *terrestrial*.

hormones Specific substances produced by the *endocrine glands* of higher animals, which are secreted into the *blood* and which are thus carried to all parts of the body where they regulate many metabolic functions of the *organism*. They are quick-acting and only a minute amount may have a profound effect on *metabolism*. Hormones are either *proteins* (e.g. *insulin*), *steroids* (e.g. *cortisone*), or relatively simple *organic compounds* (e.g. *adrenaline*).

hornblende A rock-forming *mineral* consisting mainly of *silicates* of calcium, magnesium, and iron.

horn silver Cerargyrite, chlorargyrite. Natural *silver chloride*, AgCl . An important ore of silver.

horsepower h.p. British unit of *power*; work done at the rate of 550 foot-pounds per second. 1 h.p. = 745.7 watts.

hot-wire instruments An electrical measuring instrument (*ammeter* or *voltmeter*) that depends upon the expansion, or change in *resistance*, of a wire heated by the passage of an *electric current*.

Hubble's constant The ratio of the distance between the *Local Group of galaxies* and a receding cluster of galaxies (see *expansion of the Universe*) to the rate at which the distant cluster recedes. The Hubble Constant therefore represents the hypothetical period of time since all the matter in the Universe was located in one 'super-dense' agglomeration, if it is assumed that its rate of expansion has been constant over this period. The value of Hubble's Constant is variously estimated as being between 5 and 10 thousand million years. Named after Edwin Hubble (1889-1953).

hue The characteristic of a *colour* that is determined by its *wavelength*.

humidity of the atmosphere A measure of the *water vapour* present in the air. It may be given in terms of *relative humidity*, or the *absolute humidity*.

humus Dark brown *colloidal* matter present in *soil* as the result of animal and vegetable *decomposition*. It is an important source of mineral nutrients for plants.

Huygens' construction Each point of a *wave front* may be regarded as a new source of secondary wavelets. Knowing the position of the wave front at any given time, the construction enables its position to be determined at any subsequent time. Named after Christian Huygens (1629-95).

Huygens' principle of superposition The resultant displacement at any point due to the superposition of any system of waves is equal to the sum of the displacements of the individual waves at that point. This principle forms the basis of the theory of *light interference*.

hydrargyrum See *mercury*.

hydrate A *compound* containing combined *water*. It is generally applied to *salts* containing *water of crystallization*.

hydrated The opposite of *anhydrous*; containing chemically combined *water*; (*salt*) containing *water of crystallization*.

hydraulic cement *Cement* that hardens in contact with *water*.

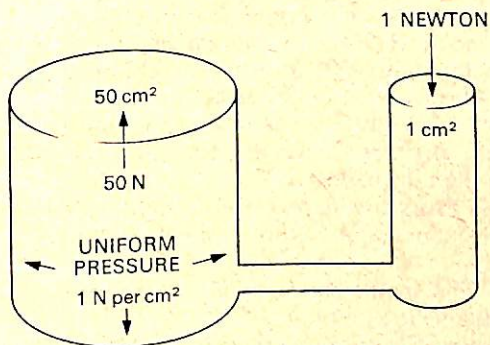


Figure 19.

hydraulic press An application of *Pascal's law*; a device whereby a *force* applied by a piston over a small area is transmitted through *water* to another piston having a large area; by this means very great forces may be obtained. See Fig. 19.

hydraulics The practical application of *hydrodynamics* to engineering.

hydrazine $\text{H}_2\text{N.NH}_2$. A fuming strongly *basic liquid*, b.p. 113°C . A powerful *reducing agent*, it is highly reactive, being used in organic synthesis and as a *rocket propellant*, either alone or mixed with the *dimethyl derivative*.

HYDRAZO GROUP

hydrazo group The *bivalent radical*— HNNH —.

hydrazoic acid Azoimide. HN_3 . A colourless poisonous *explosive liquid*, b.p. 37°C ., that forms explosive salts with heavy metals. The salts are called *azides*.

hydride A *binary compound* with hydrogen.

hydriodic acid HI. A *solution* of the colourless gas, hydrogen iodide, in water.

hydro- Prefix denoting water; e.g. *hydrogen*—water producer. In chemical nomenclature, it often denotes a *compound* of hydrogen; e.g. *hydrochloric acid*.

hydrobromic acid HBr. A *solution* of the pale yellow gas, hydrogen bromide, in water.

hydrobromide A salt formed when an *organic base* (e.g. an *alkaloid*) combines with *hydrobromic acid*. The salt so formed is usually more *soluble* than the base.

hydrocarbons *Organic compounds* that contain only carbon and hydrogen. They are classified as either *aliphatic* or *aromatic compounds* (or a combination of both). Hydrocarbons may be either *saturated* or *unsaturated compounds*.

hydrochloric acid Muriatic acid, spirits of salts. A *solution* of the colourless pungent gas hydrogen chloride, HCl , in water. The concentrated acid contains 35%–40% HCl by weight, and is a colourless fuming, corrosive *liquid*. It is manufactured by the action of *sulphuric acid*, H_2SO_4 , on *sodium chloride*, or by the direct chemical combination of hydrogen and chlorine obtained by the *electrolysis* of brine. Used in chemical industry.

hydrochloride A salt formed when an *organic base* (e.g. an *alkaloid*) combines with *hydrochloric acid*. The salt so formed is usually more *soluble* than the base.

hydrocyanic acid Prussic acid, hydrogen cyanide. HCN . A colourless, intensely poisonous *liquid* with a smell of bitter almonds. B.p. 26.5°C .

hydrodynamics The mathematical study of the *forces*, *energy*, and *pressure* of *liquids* in motion.

hydroelectric power *Electrical energy* obtained from water-power, the latter being used to drive a *dynamo*.

hydrofluoric acid 1. A *solution* of hydrogen fluoride, HF , in water. 2. The compound HF itself, a colourless, corrosive fuming *liquid*, b.p. 19.5°C ., that attacks *glass* and is used for etching glass.

hydrogel A *colloidal gel* in which water is the dispersion medium.

hydrogen H. Element. A.W. 1.00797. At. No. 1. A colourless odourless, tasteless gas, which forms *diatomic* molecules. The lightest substance known. It is inflammable, and combines with oxygen to form water. It occurs as water, H_2O , in *organic compounds*, and in all living things. It is manufactured by the *Bosch process* and by *electrolysis*. Used in the *oxy-hydrogen burner*, as a *reducing agent*, in the

manufacture of synthetic ammonia (see *fixation of atmospheric nitrogen*) and of synthetic oil (see *Fischer-Tropsch process*), and for *hydrogenation of oils*. Three isotopes of hydrogen are known; the two 'heavy' isotopes, *deuterium* and *tritium*, are of importance in *nuclear physics*.

hydrogen arsenide See *arsine*.

hydrogenation Subjecting to the chemical action of, or causing to combine with, hydrogen.

hydrogenation of coal The manufacture of artificial mineral oil from coal by the action of hydrogen. This depends on causing the carbon in coal to combine with hydrogen to form *hydrocarbons*. See *Bergius process*, *Fischer-Tropsch process*.

hydrogenation of oils Artificial hardening of *liquid animal and vegetable oils* by the action of hydrogen. Liquid *fats and oils* contain a high percentage of liquid *triolein*, $C_{57}H_{104}O_6$, which may be converted into a solid *tristearin*, $C_{57}H_{110}O_6$, by the action of hydrogen in the presence of a finely divided nickel catalyst; the result being a hard fat of higher *melting point*.

hydrogen bomb See *nuclear weapons*.

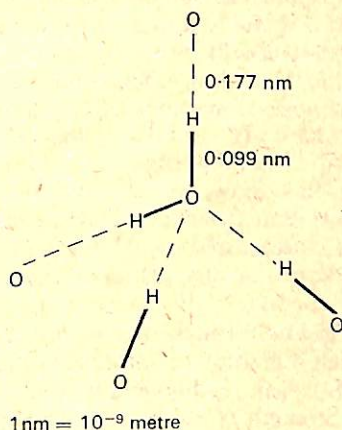


Figure 20.

hydrogen bond A weak *electrostatic* chemical bond that forms between covalently bonded (see *valence*, *electronic theory of*) hydrogen atoms and a strongly *electronegative* atom with a *lone pair of electrons* (e.g. oxygen, nitrogen, fluorine). Ice crystals are held together by this type of bond, a *tetrahedral* structure being built up as in Fig. 20 (where the dotted lines represent hydrogen bonds). When ice melts this structure breaks down but some hydrogen bonds continue to exist, and liquid *water* consists of groups of water molecules held together by hydrogen bonds. The hydrogen bond is

HYDROGEN BROMIDE

of enormous importance in biochemical processes, especially the N—H - - - N bond, which enables complex *proteins* and *nucleic acids* to be built up. Life would be impossible without this type of linkage.

hydrogen bromide See *hydrobromic acid*.

hydrogen chloride See *hydrochloric acid*.

hydrogen cyanide See *hydrocyanic acid*.

hydrogen electrode A *half cell* used as a standard for measuring *electrode potentials*, for which purpose it is assigned a potential of zero. It consists of a platinum electrode, over which hydrogen is bubbled, immersed in a dilute acid. This arrangement is designed to produce a standard concentration of hydrogen ions. See also *redox reaction*.

hydrogen fluoride See *hydrofluoric acid*.

hydrogen iodide See *hydriodic acid*.

hydrogen ion A positively charged hydrogen atom; a *proton*. The general properties of *acids* in *solution* are due to the presence of hydrogen ions.

hydrogen ion concentration The number of grams of *hydrogen ions* per litre of *solution*. It is useful as a measure of the *acidity* of a solution and in this context is usually expressed in terms of $\text{pH} = \log_{10} 1/[\text{H}^+]$, where $[\text{H}^+]$ is the hydrogen ion concentration. As pure water at ordinary *temperatures* dissociates slightly into hydrogen ions and *hydroxyl ions* ($\text{H}_2\text{O} = \text{H}^+ + \text{OH}^-$), the concentration of each type of ion being 10^{-7} mole per litre, the pH of pure water will be $\log_{10} 1/10^{-7} = 7$; this figure is accordingly taken to represent neutrality on the pH scale. If *acid* is added to water its hydrogen ion concentration will increase and its pH will therefore decrease. Thus a pH below 7 indicates acidity and similarly a pH in excess of 7 indicates alkalinity.

hydrogen peroxide H_2O_2 . A thick syrupy *liquid*, b.p. 150.2°C .; the usual form in which it is sold is a *solution* of the pure compound in water. It gives off oxygen readily, and is used as a *disinfectant* and *bleaching agent*. Strength of solution is usually given in terms of 'volume strength'; thus, 10 volume hydrogen peroxide will evolve 10 times its own volume of oxygen gas.

hydrogen phosphide See *phosphine*.

hydrogen sulphide H_2S . A colourless poisonous gas with a smell of bad eggs. It is formed by the *decomposition* of organic matter containing sulphur and occurs naturally in some mineral waters. It is prepared by the action of dilute *acids* on *sulphides* of *metals*; used in chemical analysis.

hydrolases A class of *enzymes* that control *hydrolysis*; e.g. *esterases*, *proteases*.

hydrolith Calcium hydride. CaH_2 . A substance that is *decomposed* by

water and used for the production of hydrogen, according to the equation. $\text{CaH}_2 + 2\text{H}_2\text{O} = \text{Ca}(\text{OH})_2 + 2\text{H}_2$.

hydrology The study of water with reference to its occurrence and properties in the *hydrosphere* and *atmosphere*.

hydrolysis The chemical *decomposition* of a substance by water, the water itself being also decomposed; the reaction is of the type $\text{AB} + \text{H}_2\text{O} = \text{A}(\text{OH}) + \text{HB}$. Salts of weak acids, weak bases, or both, are partially hydrolyzed in solution; esters may be hydrolyzed to form an alcohol and acid. See *saponification*.

hydrometer An instrument for measuring the density or relative density of liquids. The common type consists of a weighted bulb with a graduated, slender stem; the apparatus floats vertically in the liquid being tested. In liquids of high density a greater length of stem is exposed than in liquids of low density.

hydronium ion Superseded name for the *oxonium ion*, H_3O^+ .

hydrophilic Having an affinity for water.

hydrophobic Having no affinity for water; water-repellent.

hydroponics Cultivation of plants without the use of soil, using instead solutions of those mineral salts that a plant normally extracts from the soil.

hydroquinone Quinol 1,4-Benzenediol. $\text{C}_6\text{H}_4(\text{OH})_2$. A white crystalline substance, m.p. 170°C . It can be reversibly oxidized to quinone, and is used as a *reducing agent*, as an *antioxidant*, and in photographic developing.

hydrosol A *colloidal solution*, as distinct from a *hydrogel*, water being the solvent.

hydrosphere The watery portion of the *Earth's crust*, comprising the oceans, seas, and all other waters. Composition by weight is given as oxygen 85.8%, hydrogen 10.7%, chlorine 2.1%, sodium 1.1%, magnesium 0.14%, not more than 0.05% of any other element being present. The chief constituents are water, H_2O , sodium chloride, NaCl , and magnesium chloride, MgCl_2 .

hydrostatics The mathematical study of forces and pressures in liquids at rest.

hydrosulphate A salt formed when an organic base (e.g. an *alkaloid*) combines with *sulphuric acid*. The salt so formed is usually more soluble than the base.

hydrosulphide A compound containing the univalent group $-\text{HS}$.

hydrous Containing water.

hydroxide A compound derived from water, H_2O , by the replacement of one of the hydrogen atoms in the molecule by some other atom or group; a compound containing the *hydroxyl group*. E.g. sodium hydroxide, NaOH .

hydroxy acid An organic acid containing hydroxyl groups in addition to carboxyl in its molecule; e.g. lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$.

HYDROXYL GROUP

hydroxyl group The *univalent* —OH group. It is present in electrovalently bonded form (see *valence, electronic theory of*) in inorganic *alkalis* and in covalently bonded form in *alcohols*.

hydroxyl ion A free *hydroxyl group* bearing a negative *electric charge*. The presence of hydroxyl ions is the cause of the characteristic properties of *alkaline solutions*.

hygro- Prefix denoting moisture, humidity. E.g. *hygrometer*.

hygrodeik A *wet and dry bulb hygrometer* with a chart attached, which enables the *relative humidity* to be obtained directly from the readings of the two *thermometers*.

hygrometer Any instrument designed to measure the *relative humidity* of the *atmosphere*.

hygroscope An instrument for showing variations of *relative humidity* of the air.

hygroscopic Having a tendency to absorb moisture.

hyoscine Scopolamine. $C_{17}H_{21}NO_4$. A colourless crystalline *alkaloid*, m.p. $82^{\circ}C.$, used in the form of its *hydrobromide* as a *sedative* and *narcotic*.

hyoscyamine $C_{17}H_{23}NO_3$. A poisonous crystalline *alkaloid*, m.p. $106^{\circ}C.$, obtained from henbane, and used in the form of its *hydrobromide* or *hydrosulphate* as a *sedative* and antispasmodic.

hyper- Prefix denoting over, above, beyond.

hyperbola A curve traced out by a point that moves so that its distance from a fixed point, the *focus*, always bears a constant ratio greater than unity to its distance from a fixed straight line, the *directrix*. The curve has two branches and is formed by a *plane* cutting a right circular *cone* when the angle the plane makes with the base is greater than the angle formed by the cone's side (see *conic sections*).

hyperbolic functions Six mathematical functions analogous to the *trigonometrical ratios*. The hyperbolic functions are *sinh*, *cosh*, *tanh*, *cosech*, *sech*, and *coth*. *Sinh x* is defined as

$$\frac{1}{2}(e^x - e^{-x})$$

and *cosh x* as

$$\frac{1}{2}(e^x + e^{-x}).$$

(See *exponential*.) The remaining functions are derived from *sinh* and *cosh*, on the same basis as the related trigonometrical ratios.

hypercharge A property of certain *elementary particles*; it is equal to the particle's *baryon number* added to its *strangeness*. This property is not conserved in *weak interactions* but it is in *strong* and *electromagnetic interactions*.

hyperfine structure of spectrum lines The very *fine structure* of certain *spectrum lines* observed when they are examined under very high resolution. The lines are caused either (a) by the presence of

different *isotopes* of the *element* emitting the spectrum, or (b) if the atomic *nuclei* of the element possess a *spin*, and therefore a resultant *magnetic moment*.

hypergolic Denoting constituents of *rocket fuels* that ignite spontaneously upon contact with some other specific constituent.

hypermetropia Long sight. A defect of vision in which the subject is unable to see near objects distinctly. It is corrected by the use of *convex spectacle lenses*.

Hyperol* Trade name of a crystalline *compound* of *urea* and *hydrogen peroxide*; $\text{CO}(\text{NH}_2)_2 \cdot \text{H}_2\text{O}_2$. It evolves *hydrogen peroxide* by the action of *water*.

hyperons A group of *elementary particles*, belonging to the class called *baryons*, which have greater *mass* than the *neutron* but very short lives. All *baryons* that are not *nucleons* are known as hyperons, but as all hyperons *decay* into *nucleons* they can be regarded as *excited nucleons*. For each hyperon there is a corresponding *anti-particle*. Hyperons are listed in Table 6 of the Appendix.

hypersonic Having a speed in excess of Mach 5. See *Mach number*.

hypertonic A *solution* is said to be hypertonic with respect to another if it has a greater *osmotic pressure*.

hypnotic (chem.) A substance producing sleep. A *sedative*.

hypo- Prefix denoting under, below.

hypo (phot.) *Sodium thiosulphate*, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$. Formerly incorrectly called 'sodium hyposulphite'. Used in *photography*. See *fixing*.

hypochlorite A *salt* of *hypochlorous acid*. Hypochlorites of sodium, potassium, and calcium are used as *disinfectants* and for *bleaching*, by virtue of their oxidizing properties.

hypochlorous acid HClO . An *acid* that only exists in *solution*, but whose *salts*, the *hypochlorites*, are used in *bleaching*.

hypocycloid The figure traced by a point on the circumference of a *circle* that rolls, without slipping, round the inside of a larger fixed circle.

hypophosphorous acid Phosphinic acid, HPH_2O_2 . A colourless *deliquescent* crystalline substance, m.p. 26.5°C . It decomposes on heating into *orthophosphoric acid* and *phosphine*. Used as a *reducing agent*.

hypotenuse The side opposite the right angle (i.e. the longest side) in a right-angled *triangle*.

hypothesis A supposition put forward in explanation of observed facts.

hypotonic A *solution* is said to be hypotonic with respect to another if it has a smaller *osmotic pressure*.

hypsometer 'Height-measurer'. An apparatus for the determination of the *boiling point* of a *liquid*. Since the boiling points of liquids depend upon the *pressure*, and the atmospheric pressure varies with

HYSTERESIS

the altitude, the apparatus may be used for the determination of altitude above sea-level.

hysteresis A physical phenomenon chiefly met in the elastic and magnetic behaviour of materials. When a body is stressed, the *strain* produced is a function of the *stress*. On releasing the stress, the strain lags behind; i.e. the strain for a given value of stress is greater when the stress is decreasing than when it is increasing. On removing the stress completely, a residual strain remains. This lagging of effect behind cause is called *hysteresis*. It also occurs in induced *magnetism*. See *hysteresis cycle*.

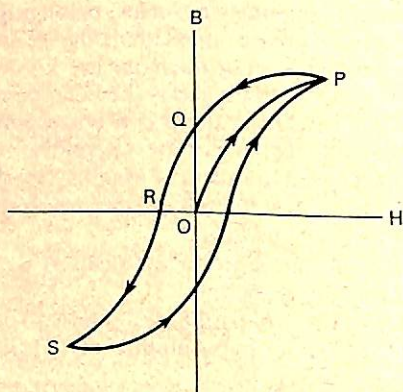


Figure 21.

hysteresis cycle A cycle of magnetizing field variations to which an initially demagnetized *ferromagnetic* substance is subjected. The magnetizing field is periodically reversed in direction until a steady state is reached in which the *magnetic induction* in the specimen at any instant is a *function* only of the magnitude of the magnetizing field and the sign of its rate of change at that instant. When this condition has been reached, a plot of induction (*B*) against magnetizing field (*H*) gives a 'hysteresis loop' or curve. See Fig. 21. When *H* is reduced to zero along *PQ*, there is a residual magnetic induction in the substance, *OQ*, which is called the *remanence*. Reversing the *polarity* of *H* along *QRS* reduces the value of *B* to zero at *R*. The strength of field, *OR*, required to reduce *B* to zero is called the *coercive force*. Rapidly reversing the field of an *electromagnet* causes *energy* to be lost by heating up the core. This 'hysteresis loss' is proportional to the area of the hysteresis loop, which should therefore be as small as possible.

I

- iatrochemistry** Medieval medical *chemistry*; early attempts at the application of drugs to medicine.
- ice** Water, H_2O , in the *solid* state, formed at the *freezing point* of water, $0^\circ C$. As it is less dense than water, water expands (See *water, expansion of*) on freezing, and ice floats on water. See *hydrogen bond*.
- ice point** The *temperature* of equilibrium between ice and water under normal atmospheric pressure (see *atmosphere*); i.e. the *melting point* of ice. The ice point is assigned the value of $0^\circ C$., in the *Celsius temperature scale*.
- iconoscope** A form of camera tube (see *camera, television*) in which an *electron beam* scans a *mosaic*, thus converting an optical image into an electrical signal.
- icosahedron** A *polyhedron* with twenty faces.
- ide** A chemical suffix denoting a *binary compound* of the two named *elements* or *radicals*; e.g. *hydrogen sulphide*, a compound of hydrogen and sulphur only.
- ideal crystal** A *crystal* whose *lattice* is perfectly regular and contains no foreign *atoms* or *ions* or other *defects* or imperfections.
- ideal gas** See *perfect gas*.
- ideal solution** A *solution* that obeys *Raoult's law* exactly.
- identity** (math.) A statement of equality between known or unknown quantities that holds true for all values of the unknown quantities. E.g. $3x = 2x + x$ irrespective of what value is assigned to x .
- IGFET** See *field-effect transistor*.
- ignis fatuus** Will-o'-wisp. A pale *flame* sometimes seen over marshy ground, probably caused by the *spontaneous combustion* of *methane*, CH_4 , or other inflammable *gases*.
- ignition** The action of setting fire to something. Initiating *combustion* by raising the *temperature* of the reactants to the *ignition temperature*; particularly the process or means of firing the explosive mixture in an *internal-combustion engine* by an *electric spark*.
- ignition temperature or point** The *temperature* to which a substance must be heated before *combustion* can take place.
- illuminance** E_v . The amount of *light* falling on unit area of a surface per second. The derived *SI unit* of illuminance is the *lux* (*lumen* per square *metre*).
- ilmenite** Natural ferrous titanate, $FeTiO_3$. An ore of *titanium*.
- image, real** (phys.) An image formed by a *mirror* or *lens* at a point through which the *rays of light* entering the observer's eye actually

IMAGE, VIRTUAL

pass. Such an image can be obtained on a screen. See Fig. 25 under *lens*.

image, virtual (phys.) An image seen at a point from which the rays of light appear to come to the observer, but do not actually do so; e.g. the image seen in a plane *mirror* or through a *diverging lens*. Such an image cannot be obtained on a screen placed at its apparent position, since the rays of light do not pass through that point. See Fig. 25 under *lens*.

image converter A device for converting an image formed by non-visible radiation (such as *infrared* or *ultraviolet radiation*) into a visible image. It usually consists of a *photocathode*, onto which the non-visible radiation is focused, and a *fluorescent screen*, which is activated by the *electrons* emitted by the photocathode.

imaginary numbers Numbers with negative squares; thus $\sqrt{-1}$ is an imaginary number, denoted by i ; $i^2 = -1$.

imidazole Iminazole, glyoxaline. $C_3H_4N_2$. A colourless soluble heterocyclic crystalline substance, m.p. 90°C ., used in organic synthesis.

imide Imido compound. A compound, derived from ammonia, containing the imido group, $\text{NH}=\text{}$, in which the two hydrogen atoms of ammonia are replaced by metal atoms or acid radicals.

imine Imino compound. A compound, derived from ammonia, containing the imino group, $\text{NH}=\text{}$, in which the two hydrogen atoms of ammonia are replaced by non-acidic organic radicals.

immersion objective Oil-immersion lens. A type of objective used in high-power microscopes, the lowest lens of the objective lens system being immersed in a drop of cedar-wood oil placed upon the slide to be examined. Such an arrangement causes more light to enter the system than if the oil were absent.

immiscible Incapable of being mixed to form a homogeneous substance; it is usually applied to liquids; e.g. oil and water are immiscible.

impact The collision of bodies. See *conservation of momentum*.

impedance Z . The quantity that determines the amplitude of the current for a given voltage in an alternating current circuit. For a circuit containing resistance R , self-inductance L , and capacitance C connected in series, the impedance of the circuit is given by the expression

$$Z = \sqrt{R^2 + (L\omega - 1/C\omega)^2}$$

where ω is a constant, the angular frequency equal to $2\pi f$, f being the frequency of the alternating current.

Imperial units A British system of units based on the pound, yard, and gallon. It is being replaced by metric units for general purposes and by SI units for scientific purposes.

impermeable Not permitting the passage of fluids.

impfing See *seeding*.

implicit function A variable quantity, x , is said to be an implicit function of y , when x and y are connected by a relation that is not explicit. See *explicit function*.

implosion The inward collapse of an evacuated vessel.

improper fraction See *proper fraction*.

impulse (phys.) A force acting during a very short time; given (for a constant force) by the product of the magnitude of the force and the time during which the force acts; it is equal to the total change of momentum produced by it.

incandescence The emission of light caused by high temperatures; white or bright-red heat.

incidence, angle of The angle between a ray of light meeting a surface and the normal to the surface at that point. See Fig. 35 under *refraction, angle of*.

inclination See *magnetic dip*.

inclinometer 1. See *dip circle*. 2. An instrument for measuring the angle of inclination that an aircraft makes with the horizontal.

incubator A box designed to maintain a constant internal temperature by the use of a thermostat; used for rearing chickens and prematurely born infants, and in bacteriology.

indene $C_6H_4.C_3H_4$. A colourless liquid hydrocarbon, b.p. $182.2^\circ C.$, obtained from coal-tar and used in organic synthesis.

indeterminacy principle See *uncertainty principle*.

index (math.) The exponent of a quantity raised to a power; the number indicating the power to which the quantity is raised. E.g. the index of a in $4a^5$ is 5.

Indian ink Chinese ink. Black ink containing a suspension of carbon.

indicator (chem.) A substance that, by a sharp colour change, indicates the completion of a chemical reaction. It is frequently used in volumetric analysis. Indicators for titrations of acids and alkalis are usually weak organic acids or bases, yielding ions of a different colour from the unionized molecules. (See *ionization*.) E.g. *litmus* is red with acids and blue with alkalis, a change in colour indicating that neutralization is complete. See *end point*.

indigo $C_{16}H_{10}N_2O_2$. An important blue vat dye, formerly extracted from plants of the genus *Indigofera*, in which it occurs as indican, a glucoside. It is now manufactured artificially on a large scale.

indium In. Element. A.W. 114.82. At. No. 49. A soft silvery-white metal, r.d. 7.31, m.p. $156.4^\circ C$. Compounds are rare. Used in electroplating and in dental alloys.

indole C_8H_7N . A yellow soluble substance, m.p. $52.5^\circ C.$, that occurs in oil of jasmin and is a decomposition product of proteins in animal intestines. Despite its unpleasant smell it is used in perfumes.

indole-3-acetic acid $C_{10}H_9NO_2$. A white crystalline substance, m.p. $168-170^\circ C.$, that promotes plant growth. See *auxins*.

INDUCED CURRENT

induced current See *induction, electromagnetic*.

induced radioactivity Artificial radioactivity. *Radioactivity* induced in naturally stable *elements* by bombarding them with *neutrons* or other high *energy* particles (or *photons*).

inductance *L*. 1. The property of an electric *circuit* as a result of which an *electromotive force* is generated by a change in the *current* flowing through the circuit (see *self-induction*), or by a change in the current of a neighbouring circuit with which it is magnetically linked (see *mutual induction*). The derived *SI unit* of inductance is the *henry*. 2. A device or circuit having this property.

induction, charging by A process of electrically charging an insulated *conductor*, using the *force* due to another nearby charge to separate the positive and negative charges existing on the conductor.

induction, electromagnetic When the *magnetic flux* through a circuit changes, an *electromotive force* is induced in the circuit. This phenomenon is called electromagnetic induction. The induced E.M.F. is equal to the rate of decrease of magnetic flux through the circuit (*Faraday's Law*). If the circuit is closed, this E.M.F. gives rise to an induced current, and the phenomenon forms the basis of the *dynamo*, *transformer*, etc. The induced current is in such a direction that its *magnetic field* tends to neutralize the change in magnetic flux producing it (*Lenz's Law*).

induction, magnetic See *magnetic induction*.

induction coil An instrument for producing a high *electromotive force* from a supply of low E.M.F. Essentially it consists of a cylindrical soft-iron core, usually laminated to prevent losses due to *eddy currents*, round which are wound two coils, the primary and the secondary. The primary coil consists of a few hundred turns; rapid variation of an *electric current* in this coil, produced by a repeated interruption or break in the circuit by a mechanism similar to that in the electric *bell*, produces an induced E.M.F. (see *induction, electromagnetic*) in the secondary coil, which contains a very large number of turns of thin wire.

induction heating A form of heating in which electrically conducting material is heated as a result of the *electric current* induced in it by an alternating *magnetic field*.

induction motor A type of *electric motor* in which an *alternating current* supply fed to the primary winding sets up a flux causing *electrical currents* to be induced in the secondary winding of the *rotor*. The interaction between these currents and the flux causes the rotor to rotate.

inductometer A calibrated variable *inductance*.

inelastic collision A collision between bodies in which there is a loss of total *kinetic energy*. Referring to *nuclear physics*, an inelastic collision in one in which an incoming particle causes *excitation* or breaking up of the struck *nucleus*.

inelastic cross-section See *cross-section*.

inert Not easily changed by *chemical reaction*.

inert gases Noble gases, rare gases. The *elements* helium, neon, argon, krypton, xenon, radon. They are all chemically inactive, although some *compounds* have been reported (e.g. XeF_2 , XeO_3 , XePtF_6 , KrF_2). Argon occurs in appreciable amounts (0.8%) in the air; the others, with the exception of radon, occur in the air in very minute amounts.

inertia (phys.) The tendency of a body to preserve its state of rest or uniform motion in a straight line.

inertial guidance A method of automatic control used in *guided missiles* that depends upon the *forces of inertia*. The *velocities* or distances covered, computed from the *acceleration* measured within the missile, are compared with data stored before launching.

inertial mass The *mass* of a body as determined by its *momentum* (in accordance with the law of *conservation of momentum*), as opposed to 'gravitational mass', which is determined by the extent to which it responds to the *force of gravity*. The *acceleration* of a falling body increases in proportion to its gravitational mass and decreases in proportion to its inertial mass. Since all falling bodies have the same constant acceleration it follows that the two types of mass must be equal.

inertial system A *frame of reference* in which bodies are not accelerated, i.e. remain at rest or move with constant *velocity*, unless acted upon by external *forces*. *Newtonian mechanics* is valid in such a system.

infinitesimal A quantity smaller than any assignable quantity; the concept is obtained by imagining a quantity decreasing indefinitely without actually becoming zero.

infinity ∞ . A quantity that is greater than any assignable quantity.

information theory A branch of *cybernetics* that attempts to define the amount of information required to control a process of given complexity. See *bit*; *noise*; *redundancy*; *equivocation*; *channel capacity*.

infrared radiation Invisible heat radiation, radiant heat. *Electromagnetic radiation* possessing *wavelengths* between those of visible *light* and those of *radio waves*, i.e. from approximately $0.8\mu\text{m}$ to 1 mm. Infrared radiation has the power of penetrating *fog* or *haze*, which would scatter ordinary visible light; thus photographs taken on a plate made sensitive to infrared radiation may often disclose detail invisible on an ordinary plate or to the naked eye.

infrared stars Celestial bodies whose principal emission is *infrared radiation*. They are believed to consist of *stars* surrounded by dust clouds. In some cases the *light* from the central star penetrates the dust so that it can be seen with *optical telescopes*.

infrasonic Having a *frequency* below the frequency of audible *sound waves*, i.e. a frequency of less than about 20 *hertz*.

INFRASOUND

infrasound Vibrations or pressure waves with a *frequency* below that of *sound*, i.e. below about 20 *hertz*.

infusible Difficult to melt; having a very high *melting point*.

infusorial earth See *kieselguhr*.

injection moulding A process by which *thermoplastic* articles are moulded. The thermoplastic material is softened in a heated chamber and then injected under pressure through an orifice into a cool closed mould.

inks Deeply coloured *liquids* of varied composition; many black and blue-black inks owe their colour to *organic compounds* of iron.

inorganic (chem.) Of *mineral* origin; not belonging to the large class of carbon compounds that are termed *organic*.

inorganic chemistry The study of the *elements* and their *compounds*. Inorganic chemistry usually includes the study of elemental carbon, its *oxides*, *metal carbonates*, and *sulphides*, while all other carbon compounds belong to the study of *organic chemistry*.

inositol Hexahydroxycyclohexane. $C_6H_6(OH)_6$. An *optically active* white crystalline solid, m.p. 228-248°C., that occurs in the *vitamin B* complex and is an essential component of animal diets. Used in medicine.

insecticide A substance used for killing insect pests.

insolation Exposure to the rays of the *Sun*.

insoluble Not capable of forming a *solution* (in *water*, unless some other *solvent* is specified). It is a relative term, since most substances have been shown to dissolve in water to some extent.

instantaneous frequency The rate of change of *phase* of an oscillation, expressed in *radians* per second divided by 2π .

insulation The prevention of the passage of *electricity*, or *heat*, by *conduction*.

insulator A non-conductor of *electricity* or *heat*.

insulin The *hormone* produced in the pancreas that controls *sugar metabolism* in the body. When injected, it lowers the *blood sugar* content and so relieves the symptoms of diabetes mellitus. Insulin is one of the few *proteins* the detailed structure of which is known.

integer A whole number.

integral 1. Consisting of whole numbers or *integers*. 2. A mathematical *function* obtained by the process of *integration*. See Appendix, Table 9.

integral calculus The branch of the *calculus* making use of the processes of *integration*. It is used for calculating *areas* and *volumes* and for other problems concerned with summation of infinitesimally small elements.

integrand A mathematical *expression* that is to be subjected to *integration*.

integrated circuit Microcircuit. A *microelectronic* circuit incorporated into a chip of *semiconductor*, usually crystalline silicon (a silicon

chip). Integrated circuits consist of whole systems rather than single components, and are used in modern *computers*. They are also used in other industries (e.g. cars, radios, etc.) in which small reliable electronic control circuits are required.

integration A mathematical process used in the *calculus*; the inverse process of *differentiation*. It gives a method of finding the area enclosed by curves, and of finding solutions to other problems involving the summation of *infinitesimals*. See Appendix, Table 9.

intensifier (phot.) A substance used to increase the *density* or contrast of an image on a photographic *film* or plate. It is usually a *compound* from which a *metal* (e.g. silver, lead, uranium, etc.) can be deposited.

intensity, electrical See *electric intensity*.

intensity, magnetic See *magnetic field strength*.

intensity of illumination See *illuminance*.

inter- Prefix denoting between, among.

interaction Mutual action between bodies, particles, or systems. In *nuclear physics* the word is often used to mean the *force* between interacting particles. See *strong* and *weak interactions*; *electromagnetic interaction*; *gravitational interaction*.

interface The surface that separates two chemical *phases*.

interference of wave motions (phys.) The addition or combination of waves; if the crest of one wave meets the trough of another of equal *amplitude*, the wave is destroyed at that point; conversely, the superposition of one crest upon another leads to an increased effect (see also *Huygens' principle of superposition*). The *colour* effects of thin films are due to interference of *light waves*; *beats* produced by two notes of similar *frequency* are the result of the interference of *sound waves*.

interferometer Any instrument that divides a *beam of light* into a number of beams and re-unites them to produce *interference*. Uses include the accurate determination of *wavelengths* of light, the testing of *prisms* and *lenses*, the examination of the *hyperfine structure of spectrum lines*, measurement of the diameters of *stars* and the determination of the number of light waves of a certain wavelength in the standard *metre*. See also *radio interferometer*.

interferon A *protein* produced in many animal *cells* as the result of the presence of *viruses* (either active or inactive) in the cell; it acts as a form of protection against these viruses.

intergalactic space The *space* between *galaxies*, in which intergalactic *matter* may occur.

intermediate (chem.) A compound used in an intermediate step in the manufacture of a final product by chemical *synthesis*.

intermediate frequency In *superheterodyne radio* receivers, the *carrier wave frequency* of the incoming radio wave is changed to a fixed

INTERMEDIATE NEUTRONS

- intermediate frequency by *heterodyne* action, for ease of amplification before detection.
- intermediate neutrons** *Neutrons with kinetic energies between those of epithermal and fast neutrons, i.e. between 100 electron-volts and 0.1 MeV.*
- intermediate vector boson** ω -particle. The *virtual particle* that has been postulated as the particle exchanged in *weak interactions*.
- intermetallic compound** A *compound* in which two or more *metals* are held together by metallic bonds. They occur in some *alloys*.
- internal-combustion engine** An *engine* in which *energy* supplied by a burning *fuel* is directly transformed into *mechanical energy* by the controlled *combustion* of the fuel in an enclosed cylinder behind a piston. Usually applied to the petrol-burning or oil-burning (*diesel*) engine.
- internal conversion** A process in which an *excited nucleus* decays to the *ground state*, the energy released being used to eject a *conversion electron* from an inner shell of the atom. The excited *ion* so formed may emit a *photon* (*X-ray*) or an *Auger electron* (see *Auger effect*).
- internal energy** Thermodynamic energy. *U*. The total *energy* associated with a system, which cannot itself usually be determined. However the change in the internal energy of a system, ΔU , is a useful *thermodynamic* quantity, and is defined by $\Delta U = q - w$ where *q* is the *heat* abstracted by the system from its surroundings and *w* is the *work* done simultaneously on the surroundings.
- internal standard line** In *spectrographic analysis* an internal standard line is a line within the *line spectrum* of the material being analysed, due to a known amount of an *element* present in, or added to, the material. See also *homologous pair*.
- internal stress** The *stress* within a solid material, e.g. *metal*, *glass*, etc., as a result of heat treatment, cold working, or non-uniform molecular structure.
- international candle** The former unit of *luminous intensity*. A point source emitting *light* uniformly in all directions at one-tenth of the rate of the Harcourt pentane lamp burning under specified conditions. Now replaced by the *candela*.
- international date line** An imaginary line on the surface of the *Earth* joining the North and South poles, approximately following the 180° *meridian* through the Pacific Ocean. This line is used to mark the internationally agreed start of a calendar day. Crossing from east to west a traveller changes the day to the next day, and crossing it from west to east goes one day back.
- International Practical Temperature Scale of 1968** This temperature scale supersedes all previous practical scales. It consists of a practical scale of *temperature* defined so that it conforms as closely as possible to the *thermodynamic temperature*. The unit of temperature is the *kelvin* (symbol *K*). The eleven fixed points on

INTRINSIC ENERGY

	T/K.	t/°C.
Triple point of equilibrium hydrogen	13.81	-259.34
Temperature of equilibrium hydrogen when its vapour pressure is 25/76 standard atmosphere	17.042	-256.108
B.p. of equilibrium hydrogen	20.28	-252.87
B.p. of neon	27.102	-246.048
Triple point of oxygen	54.361	-218.789
B.p. of oxygen	90.188	-182.962
Triple point of water	273.16	0.01
B.p. of water	373.15	100
F.p. of zinc	692.73	419.58
F.p. of silver	1235.08	961.93
F.p. of gold	1337.58	1064.43

the scale are given in the table. Between these points *interpolation* is made with a defining formula using a platinum *resistance thermometer*. Above the *freezing point* of gold a radiation *pyrometer* is used based on *Planck's Law of Radiation*.

interplanetary space The *space* between the *planets* within the *solar system*.

interpolation The process of filling in intermediate values or terms of a series between known values or terms.

interrupted continuous waves ICW. A *continuous wave electromagnetic radiation* switched on and off at an *audio-frequency*.

interstellar matter Clouds of hydrogen *atoms* or *molecules*, mixed with a small proportion of dust, that exist between *stars*. The *density* of these clouds is very low, ranging between some 10^7 and 10^9 atoms per m^3 (compared to about 10^{25} molecules per m^3 for a *perfect gas* for S.T. P.).

interstellar space The *space* between *stars* within a *galaxy*, in which *interstellar matter* may occur.

interstitial An additional *atom* or *ion* situated between the normal sites in a *crystal lattice*, causing a *defect*.

interstitial compound See *compound, interstitial*.

intra- Prefix denoting within; e.g. *intra-molecular forces* are forces within the *molecule*, while *inter-molecular forces* are forces between molecules.

intrinsic energy It is assumed in calculations in *thermochemistry* that every substance possesses a definite quantity of *intrinsic energy*, i.e. energy that is inherent in the substance and may be in part released in the form of *heat* if the substance takes part in a *chemical reaction*. In a chemical reaction, no energy is gained or lost, and the sum of the intrinsic energies of the reacting substances is equal to the sum of the intrinsic energies of the final products plus or minus the energy given out or absorbed as heat during the reaction. See

INTRINSIC SEMICONDUCTOR

Hess's law. In *thermodynamics* the intrinsic energy of a material system is its total store of energy of all kinds. The absolute magnitude is not usually important, but changes in the intrinsic energy of a system, which depend only upon its initial and final conditions (and are therefore independent of the path of change), are used in thermodynamic calculations.

intrinsic semiconductor See *extrinsic semiconductor*.

inulin ($C_6H_{10}O_5$)₆.H₂O. A *soluble polysaccharide* consisting of *fructose* units; it occurs in many plants as a stored food. Used in making bread for diabetics.

Invar* An alloy containing 63.8% iron, 36% nickel, 0.2% carbon that has a very low coefficient of *expansion*. Used for balance wheels of watches and in other accurate instruments, which would otherwise be affected by *temperature* changes.

inverse square law The intensity of an effect at a point *B* due to a source at *A* varies inversely as the *square* of the distance *AB*. Examples include the *illumination* of a surface, *gravitational field*, field due to an *electric charge*, etc. Thus, the illumination of a surface 1 metre away from a source will be 9 times as great as that of a surface 3 metres away.

inverse trigonometrical functions If $y = \sin x$ (see *trigonometrical ratios*), then the inverse trigonometrical function of x is $\sin^{-1}y$ (or *arc sin y*), where $\sin^{-1}y$ is the *angle* whose sine is y . Similar inverse functions exist for the other trigonometrical and *hyperbolic* ratios.

inverse variation One quantity is said to vary inversely as another, or to be inversely proportional to another, if the *product* of the two is a constant.

inversion of cane-sugar The conversion of *cane-sugar* (*sucrose*, $C_{12}H_{22}O_{11}$) into a mixture of equal amounts of *glucose* and *fructose*, two isomeric sugars (see *isomerism*) having the formula $C_6H_{12}O_6$. The action is one of *hydrolysis* and may be carried out by the action of the *enzyme invertase*, or by boiling with dilute *acids*. The resulting mixture is *laevorotatory*, while a solution of cane-sugar is *dextrorotatory*, inversion of the *optical rotation* being thus obtained.

inversion temperature See *Joule-Thomson effect*.

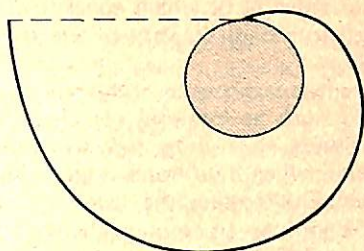
invertase Sucrase. An enzyme contained in *yeast* that converts *cane-sugar* into *glucose* and *fructose*. See *inversion of cane-sugar*.

inverter A device for converting *direct current* into *alternating current*.

invert sugar A *mixture* of *glucose* and *fructose* in equal proportions, obtained by the *inversion of cane-sugar*.

in vitro Said of experiments involving biological or biochemical processes that are carried out in 'glass' (i.e. after the *cells* or *tissues* in which the processes occur have been removed from the *organism* to which they belong) rather than in the living organism, when they are said to take place 'in vivo'.

in vivo See *in vitro*.



INVOLUTE OF A CIRCLE

Figure 22.

involute The curve formed when a piece of string is unwound from, or wound on to, another curve (the *evolute*). See Fig. 22.

iodate A salt of *iodic acid*.

iodic acid HIO_3 . A colourless or yellow *soluble* powder formed by the *oxidation* of iodine with *nitric acid*.

iodide A *binary compound* with iodine; salt of *hydriodic acid*, HI .

iodine I. Element. A.W. 126.90. At. No. 53. A blackish-grey, crystalline *solid*. R.d. 4.95, m.p. 114°C ., b.p. 184°C . It is very *volatile*, giving off a violet vapour; iodine is slightly soluble in water but readily soluble in *alcohol* (giving 'tincture of iodine') and in *potassium iodide* solution, KI . Compounds occur in seaweed; sodium iodate, NaIO_3 , occurs in crude *Chile saltpetre*. It is essential to the functioning of the thyroid gland; lack of iodine in the diet is a cause of goitre. Used in medicine, chemical analysis, and *photography*. The *radioisotope* $^{131}_{53}\text{I}$, (half-life 8.6 days) is used in the treatment and diagnosis of disorders of the thyroid gland.

iodine number Iodine value. Hübl number. A measure of the degree of unsaturation (content of double bonds) of a product, such as an oil or fat; it is expressed in grams of iodine absorbed by 100 g of the given substance.

iodoform CHI_3 . A yellow, crystalline *solid* with a peculiar odour. M.p. 119°C . Used as an *antiseptic*.

ion An electrically charged atom or group of atoms. Positively charged ions (*cations*) have fewer *electrons* than is necessary for the atom or group to be electrically neutral; negative ions (*anions*) have more. Thus, the *proton*, the hydrogen atom without its circum-nuclear electron, is a *hydrogen ion*; the *alpha-particle* is a helium ion. Gaseous ions can be produced in *gases* by *electric sparks*, the passage of energetic charged particles, X-rays, *gamma-rays*, *ultraviolet radiation*, etc. Ions in *solution* are due to the *ionization* of the dissolved substance (see *ionic hypothesis*).

ION ENGINE

ion engine A type of *reaction propulsion* engine for propelling *rockets* in *space*, the exhaust jet of which consists of a stream of positive *ions* accelerated to a high *velocity* by *electrostatic* repulsion from the engine body.

ion exchange Certain substances have the power of acting on *solutions* containing *ions*, such as solutions of *salts*, and replacing some of the ions by others; e.g. in a typical *cation* exchange ('base exchange') action, when *hard water* is passed through a suitable ion exchange resin or a *zeolite*, the calcium ions in the water are replaced by sodium ions. In *anion* exchange *acid radicals* or anions are exchanged similarly. Ion exchange has many important industrial uses in addition to water softening.

ionic bond An electrovalent bond. See *valence*, *electronic theory* of.

ionic crystal See *electrovalent crystal*.

ionic hypothesis The hypothesis originally introduced to explain the phenomena of *electrolysis*, etc. Ionic *compounds* consist of oppositely charged *atoms* or groups of atoms termed *ions*. When an *electric current* is passed through such a compound in the dissolved or molten state, the ions are attracted to the oppositely charged *electrodes*.

ionic strength A measure of the intensity of the *electrical field* due to the *ions* in a *solution* of an *electrolyte*. It is defined as half the sum of the terms obtained by multiplying the *molality* of each ion by the square of its *valence*.

ionization The formation of *ions*.

ionization chamber A device for measuring the amount of *ionizing radiation*. It consists of a gas-filled chamber containing two *electrodes* (one of which may be the chamber wall) between which a *potential difference* is maintained. The radiation ionizes gas in the chamber and an instrument connected to one electrode measures the *ionization current* produced.

ionization current The *electric current* produced by the movement of *ions* or *electrons* in an *electric field* as a result of *ionizing radiation*.

ionization potential Ionization energy. *I*. The work that must be done, measured in *electron-volts*, to remove an *electron* from an *atom*. (See *atom*, *structure of*.) More work is required to remove the second electron from an atom and each subsequent electron requires additional work. Table 7 in the Appendix gives the first five ionization potentials for the commonest atoms.

ionizing radiation Radiation (either *electromagnetic* or corpuscular) that is capable of causing *ionization*, either directly or indirectly. *Electrons* and *alpha particles* are considerably more effective in this respect than *neutrons* or *gamma-rays*.

ion mobility The *velocity* of an *ion* in a unit *electric field*.

Ionol* BHT, butylated hydroxytoluene. 2,6-Di-*tert*-butyl-4-methyl-

phenol. A white crystalline substance, m.p. $70^{\circ}\text{C}.$, used as an antioxidant.

ionomer resins *Synthetic resins cross-linked (see cross-linkage) through ionized carboxyl groups in their macromolecules.* Although they have the usual properties of cross-linked polymers, they can be processed like *thermoplastic resins*.

ionone $\text{C}_{13}\text{H}_{20}\text{O}$. A yellow optically active soluble liquid ketone, b.p. $140\text{--}146^{\circ}\text{C}.$, used in perfumes.

ionosphere The region of the Earth's *upper atmosphere* in which *free electrons* rising from *ionization* occur, mainly as a result of *ultraviolet radiation* and *X-rays* from the *Sun*. The ionosphere is useful in that it enables intercontinental *radio* transmission round the curved surface of the Earth to be achieved, as a result of its property of reflecting *electromagnetic radiations* of *radio frequencies* (see *sky wave*); but it is an obstacle to *radio astronomy* because it reflects a large proportion of the radiation that arrives from extra-terrestrial sources. The ionosphere is usually divided into three regions: the D-region between 50 and 90 kilometres above the Earth, the E-region (the *Heaviside-Kennelly layer*) between 90 and 150 km, and the F-region (the *Appleton layer*) above 150 km. See Fig. 44 under *upper atmosphere*. At night the electron concentration in the E-region falls off due to recombination with *ions*, but the F-region remains substantially ionized owing to the lower *density* of ions and their consequent infrequency of collisions with electrons. With the advent of artificial Earth *satellites* it is now possible to study the electron density of the different regions of the ionosphere from the top side.

ionospheric wave See *sky wave*.

ion pump A high-vacuum pump in which gas is removed from a system by ionizing the atoms or molecules and adsorbing the resulting *ions* on a surface, usually of a metal.

iridium Ir. Element. A.W. 192.2. At. No. 77. A rare *metal* resembling, and occurring together with, platinum. R.d. 22.42, m.p. $2410^{\circ}\text{C}.$ It is extremely hard and resistant to chemical action. *Alloys* of platinum and iridium are used for fountain-pen nib-tips, *crucibles* for fine analytical work, and numerous other purposes where extreme hardness and a high *melting point* are required.

iris 1. The coloured part of the eye of vertebrates. 2. A diaphragm forming an adjustable opening over a *lens* in an optical instrument.

iron Fe. (Ferrum.) Element. A.W. 55.847. At. No. 26. A white magnetic *metal*, r.d. 7.86, m.p. $1535^{\circ}\text{C}.$ Physical properties are greatly modified by the presence of small amounts of other metals and of carbon. It occurs as *magnetite*, Fe_3O_4 ; *haematite*, Fe_2O_3 ; *siderite*, FeCO_3 ; *limonite*, hydrated Fe_2O_3 ; and as *pyrites* in combination with sulphur. Iron is extracted from its ores by the *blast furnace* process. According to the method and conditions of

IRON, COMPOUNDS OF

working and cooling, the carbon in iron and steel may be present in various forms, upon which the particular properties of the metal depend. *Compounds* of iron are essential to the higher forms of life. See *pig iron*; *cast iron*; *wrought iron*.

iron, compounds of See under the required *ferric* or *ferrous* compound.
iron alum See *ferric alum*.

irradiation Exposure to *radiation* of any kind. Artificial *radioisotopes* are made by irradiation of stable isotopes with *neutrons* in a *nuclear reactor*. Intense irradiation can alter the physical and chemical properties of *solids*, but even small doses may be used for sterilization of food owing to the sensitivity of biological *cells* to irradiation by *ionizing radiation*.

irreversible process Any process, except one that is a completely *reversible process*.

irreversible reaction A *chemical reaction* that proceeds to completion; the resulting products do not react to form the original substances. See *chemical equilibrium*.

irritability The property of living *organisms* that enables them to respond to external stimuli.

isatin $C_8H_5NO_2$. An orange *soluble* crystalline substance, m.p. $203-5^\circ C.$, used in the manufacture of *dyes*.

isenthalpic Of equal *enthalpy*.

isentropic Of equal *entropy*.

isinglass A product containing about 90% *gelatin*, made from the swimming bladders of fish. Used for clarifying alcoholic beverages.

iso- 1. Prefix denoting equal. 2. (chem.) Prefix denoting an *isomer* with a branched chain.

isobar A line connecting points having equal (atmospheric) *pressure*.

isobaric surface A surface of equal (atmospheric) *pressure*. An altimeter will record constant height when moving along such a surface. The intersection of an isobaric surface with the ground is along an *isobar*.

isobars *Isotopes* of different *elements* that have different *atomic numbers* but identical *mass numbers*. E.g. the tin isotope, $^{115}_{50}Sn$, and the indium isotope, $^{115}_{49}In$, are isobars, 115 being the mass number and 50 and 49 the atomic numbers. Isobars have the same number of *nucleons*, but different numbers of *protons* in their *nuclei*.

isochore A line that graphically represents the relationship between the *pressure* and the *temperature* of a *liquid* or *gas*, the *volume* of the system being kept constant.

isochromatic film See *orthochromatic film*.

isocline A line connecting points of equal angle of *magnetic dip*.

isocyanate A *salt* or *ester* of *isocyanic acid*; a *compound* containing the $-NCO$ group.

isocyanic acid $\text{HN}=\text{C}=\text{O}$. An unstable *tautomer* of *cyanic acid*, which forms stable *salts* called *isocyanates*.

isodiapheres *Nuclides* in which the difference between the number of *neutrons* and *protons* is the same, e.g. a nuclide and its decay product after it has emitted an *alpha-particle* are isodiapheres.

isodimorphism The phenomenon of a *dimorphous* substance being isomorphous (see *isomorphism*) with another dimorphous substance in both its forms.

isodynamic line A line passing through points of equal *horizontal intensity* of the Earth's magnetic field (see *magnetism*, *terrestrial*).

isoelectric point The pH value at which a substance or system (e.g. a *protein solution*) is electrically *neutral*; at this value *electrophoresis* does not occur when a direct *electric current* is applied.

isogonal line A line passing through points of equal *magnetic declination*.

isogonism (chem.) A type of *isomorphism* in which two substances having little or no chemical resemblance have the same crystalline form.

isokom A line joining points of equal *viscosity* on a *phase diagram*.

isoleucine A colourless crystalline *amino acid*. See Appendix, Table 5.

isomegetic solutions *Solutions* formed of *solute molecules* of the same size.

isomeric Exhibiting *isomerism*.

isomerism 1. The existence of two or more chemical *compounds* with the same *molecular formula* but having different properties owing to a different arrangement of *atoms* within the *molecule*. E.g. ammonium cyanate, NH_4CNO , and *urea* $\text{CO}(\text{NH}_2)_2$ are isomers. See also *stereoisomerism*; *cis-trans isomerism*; *optical isomerism*.

2. In *nuclear physics*, *nuclei* having the same *atomic number* and the same *mass number*, but which exist in different *energy states*, are said to be isomeric. E.g. a nucleus in its *ground state* and a nucleus in a *metastable* excited state are isomers.

isomers See *isomerism*.

isometric 1. Referring to a system of *crystallization* in which the axes are at right angles to each other. 2. A method of projecting a drawing (*isometric projection*) in which the three axes are equally inclined to the surface of the drawing, and all lines are drawn to scale. 3. A line on a *graph* (*isometric line*) showing change of *temperature* with *pressure*, when the *volume* is kept constant.

isomorphism Similarity or identity of crystalline form, usually indicating similar or analogous chemical composition; e.g. the *alums* are isomorphous.

isooctane $(\text{CH}_3)_3\text{CCH}_2\text{CH}(\text{CH}_3)_2$. The *isomer* of *octane* used in defining *octane numbers*.

isophthalic acid $\text{C}_6\text{H}_4(\text{COOH})_2$. The *meta-isomer* of *phthalic acid*,

ISOPRENE

m.p. 345-7°C., used in the manufacture of synthetic *resins* and *plasticizers*.

isoprene $\text{CH}_2\text{:CH.C}(\text{CH}_3)\text{:CH}_2$. A colourless *liquid*, b.p. 34°C. Natural *rubber* consists mainly of a polymer of isoprene. See *polymerization*.

isosceles triangle A *triangle* having two of its sides equal.

isospin See *isotopic spin*.

isosterism The phenomenon of substances having *molecules* with the same number of *atoms* and the same total number of *electrons*; this leads to similarity in physical properties. E.g. *carbon dioxide*, CO_2 , and *nitrous oxide*, N_2O .

isotactic polymer See *atactic polymer*.

isotherm Isothermal line. A line connecting points at an equal *temperature*.

isothermal change A change that takes place at constant *temperature*. E.g. the isothermal expansion of a *gas*. See *adiabatic*.

isotones *Atoms* whose *nuclei* contain the same number of *neutrons* but have a different *atomic number*.

isotonic solutions *Solutions* having the same *osmotic pressure*, being of the same *molar concentration*.

isotopes *Atoms* of the same *element* (i.e. having the same *atomic number*) that differ in *mass number*. The isotopes of an element are identical in chemical properties, and in all physical properties except those determined by the *mass* of the atom. The different isotopes of an element contain different numbers of *neutrons* in their *nuclei*. Nearly all elements found in nature are mixtures of several isotopes. See *atom*, *structure of*.

isotopes, separation of As the *isotopes* of an *element* have identical chemical properties but some slightly different physical properties, their separation depends upon physical operations. The following methods are used: *diffusion* (either *gaseous* or *thermal*); *distillation*; centrifuging of *gases* or *liquids*; *electrolysis* (depending upon different rates of discharge or *ionic mobility* of isotopic *ions*); electromagnetic or electrostatic methods (depending upon different mass-to-charge ratios between isotopic ions and their consequent separation in a steady *magnetic field* or an *electric field* varied at *radio frequencies*).

isotopic number Neutron excess. The difference between the number of *neutrons* in an *isotope* and the number of *protons*.

isotopic spin Isospin. Isobaric spin. A *quantum number*, I , used to work out the properties of groups of *elementary particles* when the members of the group are identical in all respects except that of *electric charge*. E.g. the *nucleon* has isotopic spin, $I = \frac{1}{2}$, and its two states, the *proton* and the *neutron* are then described as different orientations of that spin in a fictitious 'isotopic space'. The word 'spin' is not intended to imply any conventional image of rotation in

this context, it is used in analogy to *angular momentum* to which the concept of isotopic spin bears a close formal resemblance. Isotopic spin is conserved in all *strong nuclear interactions*.

isotopic weight The *atomic weight* of an individual *isotope*. Isotopic weights are very nearly *integral* (whole numbers), the *integer* being called the *mass number* of the isotope concerned.

isotropic Exhibiting uniform properties throughout, in all directions.

-ite A suffix denoting, in chemical nomenclature, a *salt* of the corresponding *-ous acid*; e.g. *sulphite* from sulphurous acid.

ivory black A form of carbon obtained from *animal charcoal*, by dissolving out *inorganic compounds*, such as *calcium phosphate*, by means of *hydrochloric acid*.

J

jasper A coloured impure form of natural *silica*, SiO_2 .

javelle water Eau de Javelle. A *solution* containing potassium hypochlorite, KOCI ; made by the action of chlorine on a cold solution of *potassium hydroxide*, KOH . Used for *bleaching* and as a *disinfectant*.

jet A very hard, lustrous form of natural carbon, allied to *coal*.

jet engine A *gas turbine* that produces a stream of hot *gas* enabling an aircraft to be propelled through the air by *reaction propulsion*. Air taken in at the front of the engine is compressed by a radial compressor. The compressed air then enters the combustion chambers providing the *oxidant* for the combustion of the *liquid fuel*. The *energy* released expands the gas and accelerates it rearwards, some of the energy of the gas being used to drive a *turbine*, which in turn operates the compressor. After leaving the turbine the gas passes to the rear jet nozzle producing forward *thrust* by reaction on the structure of the jet tube.

jet propulsion See *reaction propulsion*.

joule The derived *SI unit* of *work* or *energy*. The work done when the point of application of a *force* of one *newton* is displaced through a distance of 1 *metre* in the direction of the force. The joule is also the work done per second by a *current* of 1 *ampere* flowing through a *resistance* of 1 *ohm*. Symbol *J*. 1 joule = 10^7 *ergs*. Named after James Prescott Joule (1818-89).

Joule's equivalent See *mechanical equivalent of heat*.

Joule's laws 1. The *intrinsic energy* of a *gas* at constant *temperature* is independent of its *volume*. Joule's law is obeyed strictly only by a *perfect gas*, real gases show deviations from it. 2. The *heat* produced by an *electric current* *I*, passing through a *conductor* of *resistance* *R*, for a time *t*, is equal to I^2Rt . If *I* is in *amperes*, *R* in *ohms*, and *t* in *seconds*, the heat produced will be in *joules*.

Joule-Thomson effect Joule-Kelvin effect. When a *gas* expands through a porous plug, a change of *temperature* occurs, proportional to the *pressure* difference across the plug. The temperature change is due partly to a departure of the gas from *Joule's law*, the gas performing internal work in overcoming the mutual attractions of its *molecules* and thus cooling itself; and partly to deviation of the gas from *Boyle's law*. The latter effect can give rise to either cooling or heating, depending upon the initial temperature and pressure difference used. For a given mean pressure, the temperature at which the two effects balance, resulting in no alteration of temperature, is called the 'inversion temperature'. Gases expanding

through a porous plug below their inversion temperature are cooled, otherwise they are heated. Named after J. P. Joule and Sir William Thomson (Lord Kelvin) (1824-1907).

JUGFET See *field-effect transistor*.

junction rectifier A *rectifier* based upon a *semiconductor junction*.

junction transistor A *transistor* having a *base electrode* and two or more electrodes connected to *semiconductor junctions*.

jupiter (astr.) A *planet*, having twelve small *satellites*, with its orbit between those of *Mars* and *Saturn*. It is the largest of the planets, diameter 142 800 kilometres. Mean distance from the *Sun* 778.34 million kilometres. *Sidereal period* ('year') = 11.86 years. *Mass* approximately 317.89 times that of the *Earth*. Surface temperature probably about -150°C .

K

- kainite** A double salt of *magnesium sulphate* and *potassium chloride*, $\text{MgSO}_4 \cdot \text{KCl} \cdot 3\text{H}_2\text{O}$, that occurs naturally in Poland and in the *Stassfurt Deposits*. A valuable source of potassium salts.
- kalium** See *potassium*.
- kaolin** See *china clay*.
- kaon** A *K-meson*. See Appendix, Table 6.
- karyo-** A prefix denoting the *nucleus* of a *cell* or its contents; e.g. 'karyotype', the sum of the morphological characteristics of the *chromosomes* of a cell.
- katabolism** See *catabolism*.
- katharometer** A device for measuring *thermal conductivity*, especially as a detector in *gas chromatography*.
- keepers of magnets** Short bars of soft iron used to prevent permanent *magnets* from losing their *magnetism*.
- Kekulé formula** The graphic representation of *benzene* first suggested by F. A. Kekulé von Stradonitz (1829-96). See *benzene ring*.
- kelp** Sea-weed or its *ash*, used as a source of iodine.
- kelvin** The *SI unit* of *thermodynamic temperature* defined as the fraction $1/273.16$ of thermodynamic temperature of the *triple point* of *water*, i.e. the triple point of water contains exactly 273.16 kelvins. The units of kelvin and *celsius* (*centigrade*) *temperature* interval are identical. A temperature expressed in degrees *celsius* is equal to the temperature in kelvins less 273.15°C . This is true both for thermodynamic temperatures and on the *International Practical Temperature Scale*. Symbol K; the name 'degree kelvin' (symbol $^\circ\text{K}$) was discontinued by international agreement in 1967. Named after Lord Kelvin (1824-1907).
- Kelvin effect** See *Thomson effect*.
- Kelvin temperature** *Temperature* expressed in *kelvins*. The same as the *absolute thermodynamic temperature*. See *thermodynamic temperature*. Symbol K.
- Kepler's laws** 1. The *planets* move about the *Sun* in *ellipses*, at one focus of which the Sun is situated. 2. The *radius vector* joining each planet with the Sun describes equal areas in equal times. 3. The ratio of the *square* of the planet's year to the cube of the planet's mean distance from the Sun is the same for all planets. Named after Johann Kepler (1571-1630).
- keratin** A *protein* forming the principal constituent of wool, hair, horns, and hoofs.
- kerosine** Kerosene. See *paraffin oil*.

Kerr cell A transparent cell (based on the *Kerr effect*) filled with a *liquid*, such as *nitrobenzene*, which contains two *electrodes* placed between two polarizing mediums. *Light* can only pass through the cell if the two planes of *polarization* are parallel. As the *Kerr effect* occurs in time intervals as short as 10^{-8} *second*, the cell may be used as a high-speed shutter, and also as a means of modulating a *laser beam*.

Kerr effect When *plane-polarized light* is reflected from a highly polished *pole* of an *electromagnet* the light becomes *elliptically polarized*. Similarly, if a *beam* of light is passed through certain transparent *liquids* or *solids* to which a *potential difference* is applied, the plane of polarization of the light is rotated through an angle that depends upon the magnitude of the applied potential difference. This effect is made use of in the *Kerr cell*. Named after John Kerr (1824-1907).

ketal An *organic* compound formed from a *ketone* and an *alcohol*; it has the general formula $RR'C(OR'')(OR''')$.

ketene $CH_2:C:CO$. A colourless gas, b.p. $-56^\circ C.$, used as an acetylating agent in the manufacture of *cellulose acetate* and *aspirin*. It is the first member of the ketene series, which has the general formula $R:C:CO$, where R represents a *bivalent radical* or two *univalent radicals*.

keto-enol tautomerism The type of *tautomerism* that occurs in *ketones* as the result of the migration of a hydrogen atom from an *alkyl group* to the *carbonyl group*. Thus, *acetone* contains in addition to ketone molecules ($CH_3.CO.CH_3$, the keto-form) a small proportion of molecules having the structure of an *unsaturated alcohol* ($CH_2:-COH.CH_3$, the enol-form).

ketones A series of *organic compounds* having the general formula $RR'C:O$, where R and R' are *univalent hydrocarbon radicals*. E.g. *acetone*, *dimethyl ketone*, $(CH_3)_2CO$.

ketose A *monosaccharide* that contains a *ketone group*.

keV the symbol for 1000 *electron-volts*.

kicksorter See *pulse height analyser*.

kieselguhr Diatomaceous earth, infusorial earth. A mass of *hydrated silica* (SiO_2) formed from skeletons of minute plants known as diatoms. It is a very porous and absorbent material, used for filtering and absorbing various *liquids*, in the manufacture of *dynamite* and in other industries.

killed spirits of salts A solution of *zinc chloride*, $ZnCl_2$, made by reacting zinc with *hydrochloric acid*. Used in soldering.

kilo- Prefix denoting a thousand in the *metric system*. Symbol k.

kilocycle A measure of *frequency* equal to 1000 cycles per second. (Equal to 1 *kilohertz*).

kilogram Kilogramme. 1000 *grams*. *SI Unit* of mass defined in terms of the international prototype in the custody of the Bureau International

KILOHERTZ

des Poids et Mesures at Sèvres near Paris. Equal to 2.204 62 lbs.
Symbol kg.

kilohertz kHz. 1000 hertz. A measure of frequency equal to 1000 cycles per second.

kilometre 1000 metres. Equal to 1094 yards, 0.6214 mile.

kiloton bomb A nuclear weapon with an explosive power equivalent to one thousand tons of T.N.T. (approximately 4×10^{12} joules).

kilowatt kW. A unit of power equal to 1000 watts.

kilowatt-hour kWh. Board of Trade unit. A practical unit of work. The work done when a rate of work of 1000 watts is maintained for 1 hour.

kinematic equations See *motion, equations of*.

kinematics The branch of *mechanics* concerned with the phenomena of motion without reference to *mass* or *force*. Kinematics deals with motion from the standpoint of measurement and precise description, while *dynamics* is concerned with the causes or laws of motion.

kinematic viscosity $\nu = \eta/\rho$. The ratio of the coefficient of *viscosity* to the *density* of a fluid. Measured in square metres per second (SI units) or stokes. 1 centistoke = 10^{-6} m²/s.

kinetic energy The energy a body possess by virtue of its motion. The kinetic energy of a mass m , moving with velocity v , is $\frac{1}{2}mv^2$. The energy will be in joules if m is in kilograms and v is in metres per second. (In c.g.s. units it will be in ergs.) The kinetic energy of rotation of a body whose *moment of inertia* about an axis is I , and whose *angular velocity* about this axis is ω , is $\frac{1}{2}I\omega^2$. Again the energy will be in joules if I is in kg m² and ω is in radians per second. (In c.g.s. units it will be in ergs.)

kinetics The study of the rates at which *chemical reactions* proceed.

kinetic theory of gases A mathematical explanation of the behaviour of gases on the assumption that gases consist of *molecules* in ceaseless motion in space, the *kinetic energy* of the molecules depending upon the *temperature* of the gas; the molecules are considered to be perfectly elastic particles that collide with each other and with the walls of the containing vessel (see *elastic collision*). The *pressure* exerted by a gas on the walls of the vessel is due to the collisions of the molecules with it. The *gas laws* may be shown to be in full agreement with this theory.

kink instability In a *thermonuclear reaction* experiment, an instability in the magnetically confined *plasma* resulting from a local deformation of the plasma. The kink tends to grow because the *magnetic lines of forces* of the self-induced confining field are crowded on the concave side of the kink.

Kipp's apparatus A device used in laboratories for the production of a supply of any gas that can be evolved by the action of a liquid on a solid without heating. The simplest form is illustrated in Fig. 23. Opening the tap T allows the liquid in C to reach the solid in B. A

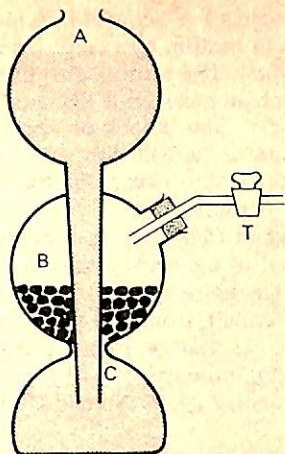


Figure 23.

reaction occurs and gas is produced. When the tap is closed, gas production continues until the liquid is forced back into B. Named after Petrus Jacobus Kipp (1808-64).

Kirchhoff's laws 1. In any network of wires the algebraic sum of the *electric currents* that meet at a point is zero. 2. The algebraic sum of the *electromotive forces* in any closed circuit or mesh is equal to the algebraic sum of the products of the *resistances* of each portion of the circuit and the currents flowing through them. Named after Gustav Robert Kirchhoff (1824-87).

kish A variety of *graphite* occasionally formed in iron *smelting* furnaces.

Kjeldahl flask A round-bottomed glass flask with a long wide neck, used in the estimation of nitrogen by *Kjeldahl's method*.

Kjeldahl's method An analytical method of determining the nitrogen content of an *organic* compound. The compound is decomposed with concentrated *sulphuric acid* to convert the nitrogen into *ammonium sulphate*. The sulphate is estimated by adding excess *alkali*, distilling the ammonia into a standard acid solution, and measuring the excess acid by *titration*. Named after Johan Kjeldahl (1849-1900).

klystron An *electron tube* used to generate or amplify *electromagnetic radiation* in the *microwave* region, by *velocity modulation*. It consists of two or more *resonant cavities* in which the electrons, from an *electron gun*, are concentrated into 'bunches'.

knocking in the internal-combustion (petrol) engine. Violent *explosions* in the cylinder, often due to over-compression of the *mixture* of air and petrol vapour before sparking.

KNOCK-ON COLLISION

knock-on collision (phys.) A process in which an *elementary particle* or *nucleus* is set in motion by being struck by another high-energy particle (or *photon*). The term is also used in relation to collisions as a result of which an *electron* is knocked out of its atomic *orbit* by some other particle. The 'knock-on' particle is the particle set in motion as the result of the collision.

knot A unit of speed equal to 1 *nautical mile* per hour. (Approximately 1.15 statute miles per hour.)

Kohlrausch's law When *ionization* is complete, the *conductivity* of an *electrolyte* is equal to the sum of the conductivities of the *ions* into which the substance dissociates.

Kovar* An *alloy* of cobalt, iron, and nickel, which has a coefficient of *expansion* similar to that of *glass*. Used for glass-to-metal seals, particularly in *thermionic valves* and *transistors*.

Krebs cycle See *citric acid cycle*. Named after Hans Adolf Krebs (born 1900).

Kroll process A process for extracting titanium or zirconium from their ores by producing the tetrachloride of the metal and reducing it under reduced pressure or by reacting it with magnesium.

Kryptol* A *mixture* of *graphite*, *carborundum*, and *clay*, used as an electrical *resistance* in electric furnaces.

krypton Kr. Element. A.W. 83.80. At. No. 36. An *inert gas*, which occurs in the *atmosphere* (1 part in 670 000); used in some *lasers*.

Kupfer-nickel Natural nickel arsenide, NiAs. An important *ore* of nickel.

L

labelled compound A *compound* in which a stable *atom* is replaced by a *radioactive isotope* of that atom. The path taken through a mechanical or biological system by such a labelled compound can be traced by the *radiation* emitted by the 'labelled atom'. See also *radioactive tracing* and *tritiated compound*.

labile Prone to undergo change or displacement; *unstable*.

lachrymator See *tear-gas*.

lactase An *enzyme* that catalyses the conversion of *lactose* into *glucose*. Present in the digestive juices of mammals.

lactate 1. A *salt* or *ester* of *lactic acid*. 2. To produce milk.

lactic acid $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. A colourless, crystalline *organic acid*, occurring in three stereoisomeric forms (see *stereoisomerism*), m.p. 18°C . *dl*-lactic acid, a mixture of equal amounts of (*dextrorotatory*) *d*-acid and (*laevorotatory*) *l*-acid, is formed by the action of certain *bacteria* on the *lactose* of milk during souring. The *d*-form, *sarcosolactic acid*, occurs in muscle tissue. The optically inactive *dl*-form is used in dyeing and *tanning*.

lactoprotein Any of the *proteins* present in milk.

lactose Milk sugar. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A hard, gritty, crystalline, *soluble*, *disaccharide*, m.p. 203°C ., less sweet than *cane-sugar*, that occurs in the milk of all mammals. *Hydrolysis* gives a mixture of *glucose* and *galactose*. In the action of certain *bacteria* on milk ('lactic acid fermentation') *lactose* is converted into *lactic acid*.

laevorotatory Rotating or deviating the plane of vibration of *polarized light* to the left (observer looking against the oncoming light). See *optical activity*.

laevulose Fructose, fruit sugar. $\text{C}_6\text{H}_{12}\text{O}_6$. See *fructose*.

lake In dyeing, a coloured *insoluble* substance formed by the chemical combination of a *soluble dye* with a *mordant*.

lambda particle An *elementary particle*, classified as a *hyperon*, that has no charge and is 2183 times heavier than an *electron*.

lambert A unit of *luminance*. The luminance of a uniform diffuser of *light* that emits one *lumen* per sq cm. Named after J. H. Lambert (1728-77).

Lambert's law of illumination The *illuminance* of a surface upon which the *light* falls normally from a *point source* is inversely proportional to the *square* of the distance between the surface and the source. If the *normal* to the surface makes an angle θ with the direction of the rays, then the *illuminance* is proportional to $\cos \theta$.

lamina A thin sheet.

LAMINAR FLOW

laminar flow The flow of a *fluid* that closely follows the shape of a streamlined surface without turbulence.

laminated iron Thin sheets of iron (or, more frequently *stalloy**) used for cores of *transformers* instead of solid iron cores, in order to reduce losses due to *eddy currents*.

lamp-black Soot; an *allotropic* form of *carbon*.

lanoline A wax-like material obtained from wool-grease and containing *cholesterol*, $C_{27}H_{45}OH$, and other complex *organic* substances. It is readily absorbed by the skin; used in ointments and cosmetics.

lanthanides Lanthanons. Rare earths. A group of rare metallic *elements* with *atomic numbers* from 57 to 71 inclusive. The properties of these *metals* are all very similar and resemble those of aluminium. The elements occur in *monazite* and other rare minerals. See Appendix, Table 8.

lanthanum La. Element. A.W. 138.91. At. No. 57. R.d. 6.2, m.p. 920°C. See *lanthanides*.

lapis lazuli Sodium aluminium silicate containing sulphur. A rare mineral of beautiful blue colour.

Laplace operator Laplacian. ∇^2 . The *differential* operator that gives the sum of the *partial derivatives* of second order with respect to each *variable*, i.e.

$$\nabla^2 u = \partial^2 u / \partial x^2 + \partial^2 u / \partial y^2 + \partial^2 u / \partial z^2 = 0$$

This *equation* is known as the 'Laplace equation'. Named after Pierre Simon Laplace (1749-1827).

large calorie Kilogram-calorie, Calorie. 1000 *calories*.

Larmor precession The orbital motion of the *electrons* about the *nucleus* of an *atom* is usually such as to give the atom a *resultant angular momentum* and a *magnetic moment*. These two properties cause the atom to precess (see *precessional motion*) about the direction of any applied *magnetic field*. This is Larmor precession; the *frequency* of this precession, known as the Larmor frequency, is equal to $eH/4\pi mv$, where e and m are the electronic charge and mass, and H is the *magnetic field strength*, and v is the velocity of the electron. Named after Sir Joseph Larmor (1857-1942).

laser Light Amplification by Stimulated Emission of Radiation. An optical *maser*. The laser produces a powerful, highly directional, *monochromatic*, and *coherent* beam of *light*. It works on essentially the same principle as the maser, except that the 'active medium' consists of, or is contained in, an optically transparent cylinder with a reflecting surface at one end and a partially reflecting surface at the other. The stimulated waves make repeated passages up and down the cylinder, some of them emerging as light through the partially reflecting end. In the *ruby laser*, the chromium *atoms* of a cylindrical shaped ruby *crystal* are optically pumped to an excited state (see *excitation*) by a flash lamp, and it can then be made to

emit *pulses* of highly coherent light (see *population inversion*). Lasers have also been constructed using a mixture of *inert gases* (helium and neon) to produce a continuous beam. Another type of laser consists of a cube of specially treated gallium arsenide, which is capable of emitting *infrared radiation* when a current is passed through it. The uses of lasers include eye surgery, *holography*, and cutting metals.

latent heat *L*. The quantity of *heat* absorbed or released in an *isothermal* transformation of *phase*. The *specific* latent heat of *fusion* is the *heat* required to convert unit *mass* of a *solid* to a *liquid* at the same *temperature*. The *specific* latent heat of *vaporization* is the *heat* required to convert unit *mass* of *liquid* to *vapour* at the same *temperature*. Measured in *joules* per *kilogram*. The corresponding *molar* latent heats are measured in *joules* per *mole*. At the *melting* and *boiling points* of a substance, the addition of *heat* causes no rise in *temperature* until the change of state is complete.

lateral In a sideways direction.

lateral inversion The inversion produced by a plane *mirror*. It is seen when the image of a printed page is observed in a mirror.

lateral velocity The component of a celestial body's *velocity* perpendicular to the *line of sight velocity*.

latex 1. A milky fluid produced by certain plants; the most important is that obtained from the rubber tree (*Hevea brasiliensis*), consisting mainly of a colloidal *suspension* of *rubber* globules in a watery liquid 2. An analogous *emulsion* or *suspension* of a synthetic rubber or similar polymer.

latitude The *angular distance* of a point from the *equator* measured upon the curved surface of the Earth. In *astronomy* it is the *coordinate* of a celestial body from a fixed *plane*. The 'galactic latitude' is the *angular distance* from the plane of the *Milky Way*. The 'celestial latitude' is the *angular distance* between the celestial body and the *ecliptic*.

latitude, lines of Parallels of latitude. Circles parallel to the *equator*, joining points of equal *latitude*; the equator itself is latitude 0°, while the poles are latitude 90°.

lattice 1. The regular network of fixed points about which *molecules*, *atoms*, or *ions* vibrate in a *crystal*. 2. In a *nuclear reactor*, a structure consisting of discrete bodies of *fissile* and non-fissile material (especially *moderator*), arranged in a regular geometrical pattern.

lattice energy The *energy* required to separate the *ions* of a *crystal* to an infinite distance from each other.

laudanum An alcoholic *tincture* of *opium*.

laughing gas See *nitrous oxide*.

LAURALDEHYDE

lauraldehyde Lauryl aldehyde. See *dodecanal*.

lauric acid Dodecanoic acid. $\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$. A white crystalline insoluble substance, m.p. 44°C ., used in the manufacture of soaps, detergents, and cosmetics.

lauroyl The univalent radical $\text{CH}_3(\text{CH}_2)_{10}\text{CO}-$.

lauryl alcohol Dodecanol. $\text{CH}_3(\text{CH}_2)_{11}\text{OH}$. A white crystalline insoluble substance, the commercial form of which consists of a mixture of isomers with m.p. in the range $20-30^\circ\text{C}$. Used in the manufacture of detergents.

lawrencium Lr. Transuranic element, At. No. 103. The only known isotope, $^{257}_{103}\text{Lw}$, has a half-life of only 8 secs.

LD50 See median lethal dose.

leaching Washing out a soluble constituent.

lead Pb (Plumbum). Element. A.W. 207.19, At. No. 82. A soft, bluish-white metal, r.d. 11.34, m.p. 327.4°C . It occurs chiefly as *galena*, PbS , and is extracted by roasting the ore in a reverberatory furnace. Compounds are poisonous. The metal is used in the lead accumulator, in alloys and in plumbing; compounds are used in paint manufacture and in petrol additives (see *tetraethyl lead*).

lead accumulator See *accumulator*.

lead acetate Sugar of lead. $(\text{CH}_3\text{COO})_2\text{Pb} \cdot 3\text{H}_2\text{O}$. A white crystalline soluble salt, m.p. 280°C ., with a sweet taste. Used as a mordant and as a drier in paints.

lead arsenate $\text{Pb}_3(\text{AsO}_4)_2$. A white crystalline substance, m.p. 1042°C ., used as an insecticide.

lead carbonate Normal lead carbonate, PbCO_3 , is a white powder that occurs naturally as *cerussite*. Basic lead carbonate, $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$, is known as white lead and is widely used as a pigment.

lead-chamber process The manufacture of sulphuric acid by the action of nitrogen dioxide, NO_2 , on sulphur dioxide, SO_2 , to give nitric oxide, NO , and sulphur trioxide, SO_3 . The former reacts with oxygen from the air to give NO_2 again; the SO_3 combines with water to give sulphuric acid, the process being carried out in large lead chambers. The process is now obsolete and has been replaced by the contact process.

lead dioxide Lead peroxide. PbO_2 . An amorphous, dark brown powder.

lead monoxide Litharge. PbO . A yellow crystalline substance, m.p. 888°C ., used in the manufacture of glass, paints, and glazes. See also red lead.

lead peroxide See *lead dioxide*.

lead tetraethyl See *tetraethyl lead*.

Leblanc process Salt-cake process. An obsolete process for the manufacture of sodium carbonate, Na_2CO_3 . Common salt is converted into sodium sulphate, Na_2SO_4 ('salt-cake') by heating with sulphuric acid. This is heated with coal and limestone; the sodium sulphate is reduced by the carbon to sodium sulphide, which

then reacts with the limestone to give sodium carbonate and calcium sulphide. It has been replaced by the *Solvay process* and by conversion of *trona*. Named after Nicolas Leblanc (1742-1806).

Le Chatelier Principle If a system in *equilibrium* is subjected to a stress, the system tends to react in such a way as to oppose the effect of the stress. Named after Henri-Louis Le Chatelier (1850-1936).

lecithins Naturally occurring complex *lipids* essentially consisting of *glycerides* in which one of the *acyl* groups is replaced by a *phosphorylcholine group*; they are chemically similar to *fats*, but additionally contain nitrogen and phosphorus.

Leclanché cell A *primary cell* with a positive *electrode* or pole of carbon surrounded by a mixture of *manganese dioxide* and powdered carbon in a porous pot. This stands in a *solution of ammonium chloride*, the *electrolyte*, in a jar, which also contains the negative electrode of zinc. When the external circuit is completed, a current flows, chlorine *ions* in the electrolyte moving towards the zinc and ammonium ions toward the carbon electrode. The chlorine ions react with the zinc to form *zinc chloride*, and the ammonium ions decompose at the positive electrode to give *ammonia* and hydrogen. The hydrogen liberated tends to cause *polarization* of the cell. This tendency is partly counteracted by the manganese dioxide, which oxidizes the hydrogen. The *E.M.F.* is approximately 1.5 volts. Leclanché cells are widely used for many purposes which require an intermittent current. The common *dry cell* is a special form of Leclanché cell. Named after Georges Leclanché (1839-82).

LED See *light-emitting diode*.

length, British units of

12 lines	= 1 inch
12 ins	= 1 foot
3 ft	= 1 yard
22 yds	= 1 chain
10 chains	= 1 furlong
8 furlongs	= 1 mile

For conversion to metric units see Appendix, Table 1.
length, metric units of

10 millimetres	= 1 centimetre
100 cm	= 1 metre
1000 m	= 1 kilometre

For conversion to British units see Appendix, Table 1. The *SI unit* of length is the *metre*.

lens Any device that causes a *beam* of *rays* to converge or diverge on passing through it. The optical lens is a portion of a *transparent* refracting medium (see *refraction of light*), usually *glass*, bounded by two surfaces, generally curved. Such lenses are classified

LENS

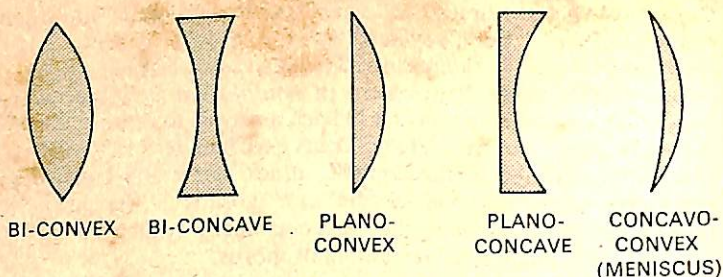


Figure 24.

CONVERGING AND DIVERGING LENSES

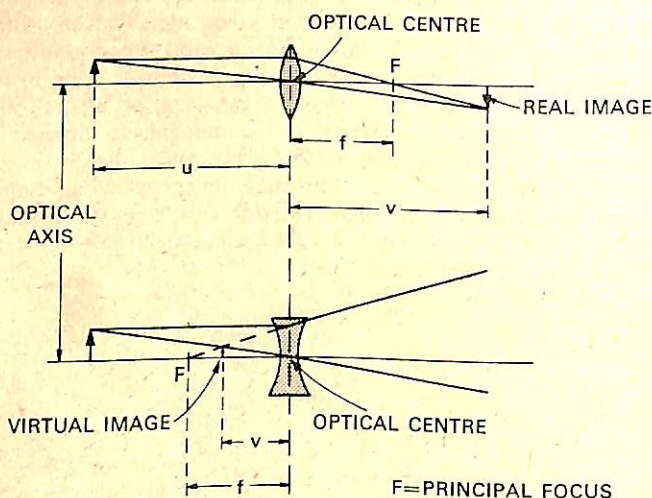


Figure 25.

according to the nature of the surfaces into bi-concave, bi-convex, plano-convex, etc. (See Fig. 24.) The centres of the spheres of which the lens surfaces are considered to form a part are termed the *centres of curvature*; the line joining these is the *optical axis*, the *optical centre* is a point on the axis within the lens; all rays passing through this point emerge without deviation. A parallel beam of light incident on a lens is made to converge (convex lens) or diverge (concave lens). The point of divergence or convergence is called a principal focus (see Fig. 25). Regarding all distances as being

measured from the optical centre, and taking all distances as positive when measured in a direction opposite to that of the incident light, the distances of the object and image from the lens are given by the formula $1/v - 1/u = 1/f$, where u and v are the distances from the lens of object and image respectively, and f is the *focal length*, i.e. the distance of the focus from the lens (see Fig. 25.) Electrostatic and electromagnetic lenses, for converging beams of *electrons* and other elementary charged particles, are also of importance, e.g. in the *electron microscope*. See *electron lens*.

lenticular Pertaining to a *lens*, especially a *bi-convex lens*, or resembling such a lens in shape.

Lenz's law When a circuit and a *magnetic field* move relatively to each other, the *electric current* induced in the circuit will have a magnetic field opposing the motion. See *induction*, *electromagnetic*. Named after Heinrich Lenz (1804-65).

lepton A collective name for *electrons*, *muons*, and *neutrinos*. They form a class of *elementary particles* that react by the *electromagnetic interaction* and the *weak interaction* but are insensitive to the *strong interaction*. There is some evidence for another type of lepton, considerably heavier than the others, called the *tau particle*. The number of leptons minus the number of corresponding anti-leptons taking part in a process is called the 'lepton number'; a quantity that appears to be conserved in all processes. All leptons have *spin* $\frac{1}{2}$, but anti-leptons have spin in an opposite direction to that of their corresponding particles. See Appendix, Table 6.

leucine A white *soluble amino acid*, m.p. 293-5°C., essential to mammals. See Appendix, Table 5.

leucocytes White *blood cells*. The cells of the *blood* that contain no *haemoglobin*. There are several types of leucocytes, the main function of which is the combating of infection. Human blood contains between 5000 and 10 000 leucocytes per cubic millimetre.

lever A rigid bar that may be turned freely about a fixed point of support, the *fulcrum*. The *mechanical advantage* of a lever is given by the ratio of the perpendicular distance of the line of action of the effort from the fulcrum, to the perpendicular distance of the line of action of the resistance from the fulcrum.

Lewis acids and bases A concept of *acids* and *bases* put forward by G. N. Lewis (1875-1946) in which an acid is defined as a substance that forms a covalent bond (see *valence*, *electronic theory of*) with a base by accepting from it a *lone pair of electrons*. A base is defined as a substance that forms a covalent bond with an acid by donating to it a lone pair of electrons.

lewisite 1. β -Chlorovinylchloroarsine. ClCH:CHAsCl_2 . An oily liquid, b.p. 190°C., developed as a 'war gas' and having *vesicant* and other lethal properties. 2. The mineral calcium titanium antimonate, $5\text{CaO} \cdot 2\text{TiO}_2 \cdot 3\text{Sb}_2\text{O}_5$.

Leyden jar A form of electrostatic capacitor of historical interest. Invented in 1745 in the Dutch town of Leyden.

libration An oscillation of the Moon's face from side to side. Due to libration, about 58% of the Moon's surface can be seen from the Earth.

Liebig condenser See *condenser* (chem.). Named after Baron von Liebig (1803-73).

ligand A single atom or a group of atoms attached to a central atom in a coordination compound. In a ligand one, two, or more atoms may be attached to the central atom, and it is referred to correspondingly as a uni-, bi-, or multi-dentate ligand.

light The agency by means of which a viewed object influences the observer's eye. It consists of electromagnetic radiation within the wavelength range 4×10^{-7} metre to 7.7×10^{-7} metre approximately; variations in the wavelength produce different sensations in the eye, corresponding to different colours. See *colour vision*.

light, velocity of The mean value is $2.997\,925 \times 10^8$ m s⁻¹ or 186 281 miles per second. The special significance of the velocity of light in the Universe was revealed by the special theory of relativity. According to this now accepted theory, the velocity of light is absolute (i.e. independent of the velocity of the observer) and represents a limiting velocity in that the velocity of no body can exceed it. The special significance of the velocity of light is apparent from its presence in the mass-energy equation, which follows from the special theory of relativity. In this equation the velocity of light appears as the 'connecting link' between mass and energy.

light-emitting diode (LED) A device used to display figures (*digital display*), etc., in calculators and other equipment giving a visual display. It consists essentially of a semiconductor diode, made from such materials as gallium arsenide, in which light is emitted at a p-n junction when electrons and holes recombine. The light emitted is proportional to the bias current and its colour depends on the type of material used.

lightness See *colour*.

lightning An electric discharge in the form of a spark or flash between two charged clouds, or between a cloud and the Earth.

lightning conductor A conductor of electricity connected to earth and ending in one or more sharp points attached to a high part of a building. It provides a direct path of low resistance to earth.

light pen An input/output computer device used with a visual display unit. When pointed at a cathode ray tube it can sense whether or not the spot is illuminated.

light quantum See *photon*.

light-year An astronomical measure of distance; the distance travelled by light (see *light, velocity of*) in one year: equal to 9.4605×10^{15} metres or $5.878\,48 \times 10^{12}$ miles.

- lignin** A complex *organic* material that occurs in the woody *tissues* of plants, often combined with *cellulose*. The preparation of pure cellulose by removing the lignin is an important step in the manufacture of pulp for the *paper* and *rayon* industries.
- lignite** Brown coal. A brownish-black, natural deposit resembling coal, which contains a higher percentage of *hydrocarbons* than ordinary coal; it is probably of more recent origin.
- ligroin** A mixture of *hydrocarbons* similar to *benzine*, but boiling in a higher temperature range (80-130°C.).
- lime** Quicklime, see *calcium oxide*; or slaked lime, see *calcium hydroxide*. The term is sometimes loosely applied to calcium salts in general.
- limestone** Natural *calcium carbonate*, CaCO_3 .
- lime-water** A solution of *calcium hydroxide*, $\text{Ca}(\text{OH})_2$, in water. It turns milky by the action of *carbon dioxide*, CO_2 , owing to the formation of *insoluble calcium carbonate*, CaCO_3 .
- limit** Limiting value (math.). A *function* of a variable quantity x , written $f(x)$, approaches a limiting value k as x approaches a value a , if the difference $k - f(a + \delta)$ may be made smaller than any assignable value by making δ sufficiently small.
- limit of spectral series** The lines appearing in the *line spectrum* of any *element* can be grouped into definite series. The shortest *wavelength* of any such series is called the limit of the series. At this series limit, the lines crowd closer and closer together from the long wavelength side.
- limonene** Dipentene. $\text{C}_{10}\text{H}_{16}$. An *optically active* liquid *terpene*, b.p. 176°-178°C., which occurs in some *essential oils*; used as a *solvent* and in the manufacture of *resins* and *surface-active agents*.
- limonite** A natural *hydrated* form of *ferric oxide*, Fe_2O_3 . An ore of iron.
- linac** See *linear accelerator*.
- linalol** $\text{C}_{10}\text{H}_{17}\text{OH}$. A colourless *liquid terpene alcohol*, b.p. 198-200°C., occurring in certain *essential oils* and used in perfumes.
- linalyl acetate** Bergamol. $\text{C}_{10}\text{H}_{17}\text{COOCH}_3$. A colourless *liquid*, b.p. 220°C., with a pleasant odour; used in perfumes and soaps.
- Linde process** A process for producing *liquid air*, based on the *Joule-Thomson effect*. Air is compressed and expanded through a nozzle, which causes it to cool. The cool air is passed through a counter-current *heat exchanger* to reduce the temperature of the incoming air. Eventually the temperature is reduced sufficiently to liquefy the air. Named after Carl von Linde (1842-1934).
- linear** 1. Arranged in a line. 2. Having only one dimension. 3. (of a mathematical expression or *equation*) Having only first *degree* terms (see also *linear relationship*). 4. (of a component, *circuit*, or piece of *electronic equipment*) Having an output directly proportional to the input.

LINEAR ABSORPTION COEFFICIENT

linear absorption coefficient α . A measure of a medium's ability to absorb radiation, but not to scatter or diffuse it (compare *linear attenuation coefficient*). It is given by $\phi_x/\phi_0 = e^{-\alpha x}$, where ϕ_0 is the initial *radiant flux* or *luminous flux* and ϕ_x is the flux after it has travelled a distance x through the medium.

linear accelerator Linac. An apparatus for accelerating *ions* to high *energies*. It consists of a row of cylindrical *electrodes* separated by small gaps and having a common axis. Alternate electrodes are connected to each other and a *high-frequency potential* is applied between the two sets of electrodes. The frequency, and the lengths of the different electrodes, are such that the ions are accelerated each time they cross a gap between two electrodes.

linear attenuation coefficient μ . A measure of a medium's ability both to absorb and to diffuse radiation (compare *linear absorption coefficient*). If a *luminous flux* or a *radiant flux*, ϕ , passes perpendicularly through a section of the attenuating medium, dl , then the linear attenuation coefficient, $\mu = 1/\phi \cdot d\phi/dl$.

linear motor A form of *induction motor*, in which the *stator* and *rotor* are linear instead of cylindrical, and parallel instead of *coaxial*.

linear relationship A relationship existing between two *variable* quantities that are directly proportional to each other. A *graph* representing the manner in which such quantities vary with each other will be a straight line.

line defect See *defect*; *dislocation*.

line of sight velocity Radial velocity. The *velocity* at which a heavenly body approaches, or recedes from, the Earth. It is measured spectroscopically by observing the shift of the spectral lines (see *spectrum*) of *elements* within the body, relative to those of the same elements on Earth. See *Doppler effect*.

line pair In *spectrographic analysis* a line pair consists of the particular spectral line (see *line spectrum*) utilized in the determination of the concentration of an *element* and the *internal standard line* with which it is compared.

line printer An output device from a *computer*, which prints a line of *characters* at a rate of between 300 and 1500 lines per minute.

lines of force See *electrical lines of force*; *magnetic lines of force*.

line spectrum A *spectrum* (*emission* or *absorption*) consisting of definite single lines, each corresponding to a particular *wavelength*; it is characteristic of an *element* in the atomic state.

Linnaean system See *binomial nomenclature*. Named after Carolus Linnaeus (1707-78).

linoleic acid $C_{17}H_{31}COOH$. A yellow oily liquid *unsaturated fatty acid*, b.p. $229^\circ C.$, which occurs in various *vegetable oils*, particularly *linseed oil*. Once known as *vitamin F*, its function in this capacity is now discredited.

linseed oil A *vegetable oil* extracted from the seeds of flax plants. It contains *glycerides* of *oleic acid* and other *unsaturated fatty acids*. Being easily oxidized and polymerized it is widely used in the *paint* and *varnish* industries and for manufacturing *linoleum*.

lipase An *enzyme* with the power of hydrolyzing (see *hydrolysis*) *fats*.

lipids Lipoids. A group of *organic compounds* that are *esters* of *fatty acids* and are characterized by being *insoluble* in *water* but *soluble* in many *organic solvents*. They are usually divided into three groups: (1) 'Simple lipids', which include *fats and oils* as well as *waxes*; (2) 'Compound lipids', which include *phospholipids* and *glycolipids*; (3) 'Derived lipids', of which the most important are the *steroids*.

lipoclastic Lipolytic. Fat-splitting; applied to *enzymes* having the power of hydrolyzing (see *hydrolysis*) *fats* into *fatty acids* and *glycerin*; e.g. *lipase*.

lipoprotein A *protein* that includes a *lipid* in its structure.

Lipowitz' alloy A fusible *alloy*, m.p. 65–70°C., consisting of 50% bismuth, 27% lead, 13% tin, and 10% cadmium.

liquation The separation of a *solid mixture* by heating till one of the constituents melts and can be drained away.

liquefaction of gases A *gas* possessing a *critical temperature* above room temperature may be liquefied merely by increasing the *pressure* on it. Otherwise, the gas must first be cooled to below its critical temperature and then compressed; or, if desired, cooled directly to its *boiling point* under normal pressure. The methods of cooling are (1) by *evaporation* under reduced pressure, as in the *cascade liquefier*; (2) by using the principle of the *Joule-Thomson effect* (see *Linde process*); (3) by causing the gas to expand against an external pressure; in so doing the gas does *work*, thereby cooling itself. This principle is used in the *Claude process*.

liquid A state of *matter* intermediate between a *solid* and a *gas*, in which the *molecules* are relatively free to move with respect to each other but are restricted by *cohesive forces* to the extent that the liquid maintains a fixed *volume*. Liquids assume the shape of the vessel containing them, but are only slightly compressible.

liquid air A pale blue *liquid*, containing mainly liquid oxygen, b.p. -182.9°C., and liquid nitrogen, b.p. -195.7°C.

liquid-crystal display A *digital display* in an electronic calculator, etc., based on *liquid-crystal* cells that change their reflectivity in an applied *electric field*.

liquid crystals Relatively large regions of regularly aligned *molecules* in *liquids* that are analogous to crystals (exhibiting *cybotaxis*) and sufficiently distinct from the bulk liquid to constitute identifiable 'mesophases'. Under the influence of an *electric field*, such phases undergo realignments leading to optical effects. See *liquid-crystal display*; *cholesteric crystals*; *nematic crystals*; *smectic crystals*.

LIQUID DROP MODEL

liquid drop model of the nucleus A hypothetical model of the atomic nucleus in which its properties are compared to those of a drop of liquid.

Lissajous figure The *locus* of the *resultant* displacement of a point on which two or more simple periodic motions are impressed. In the common case, two periodic motions are at right angles and are of the same *frequency*. The Lissajous figures then become, in general, a series of *ellipses* corresponding to the possible differences of *phase* between the two motions. Named after Jules Lissajous (1822-80).

litharge See *lead monoxide*.

lithium Li. Element. A.W. 6.939. At. No. 3. A light, silvery-white *alkali metal*, m.p. 179°C., r.d. 0.534. It is the lightest *solid* known. Chemically it resembles sodium, but is less active. Used in *alloys*.

lithium chloride LiCl. A white *soluble deliquescent* substance, m.p. 614°C., used as a *flux* and in mineral waters.

lithium hydride LiH. A white crystalline substance, m.p. 680°C., used in organic synthesis as a *reducing agent*.

lithopone A *mixture* of *zinc sulphide*, ZnS, and *barium sulphate*, BaSO₄. Used in *paints* as a non-poisonous substitute for *white lead*.

lithosphere See *Earth's crust*.

litmus A *soluble* purple substance of vegetable origin; it is turned red by *acids* and blue by *alkalis*. Used as an *indicator*.

litre Unit of *volume* in the *metric system*. Formerly defined as the volume of 1 *kilogram* of pure water at 4°C. and 760 mm pressure (which is equivalent to 1000.028 cc). This definition still applies for purposes of the 1963 Weights and Measures Act. However, in *SI units* the litre is a special name for the cubic decimetre, but is not used for high precision measurements. For approximate purposes 1 litre = 1000 cc, and the symbol ml is often used synonymously with cc, though this practice is now deprecated.

liver of sulphur A *mixture* of *sulphides* and other sulphur compounds of potassium, obtained by fusing *potassium carbonate*, K₂CO₃, with sulphur. Used as an *insecticide* and *fungicide* in gardening.

lixiviation The extraction of *soluble* material from a *mixture* by washing with *water*.

loaded concrete Normal *concrete* to which has been added some material containing *elements* of high *atomic number* (e.g. iron or lead shot). Used in the shielding of *nuclear reactors*.

local group of galaxies The cluster of *galaxies* to which the *Galaxy* belongs. Distant clusters of galaxies are receding from the local group. See *expansion of the Universe*.

local oscillator The *oscillator* in a *heterodyne* or *superheterodyne radio* receiver that produces the *radio frequency* oscillation with which the received wave is combined.

locus (math.) The locus of a point is the line that can be drawn through

adjacent positions of the point, thus tracing out the path of the point in space.

lodestone A magnetic variety of natural iron oxide. Fe_3O_4 , *magnetite*.

logarithmic scale A scale of measurement in which an increase of one unit represents a tenfold increase in the quantity measured (for common *logarithms*).

logarithms If a number, a , is expressed as a power of another number, b , i.e. if $a = b^n$, then n is said to be the logarithm of a to base b , written $\log_b a$. Common logarithms are to base 10. Multiplication, division, and other computations are shortened by the use of common logarithms; the addition of logarithms of numbers gives the logarithm of the *product* of the numbers; similarly *division* can be performed by subtraction of the logarithms. Logarithms corresponding to ordinary numbers have been tabulated, and calculations are carried out by the use of such tables. Natural or Napierian logarithms are to the base 'e' (which has the value 2.718 28). $\log_e a = 2.303 \log_{10} a$. See also *characteristic*; *mantissa*; *exponential*.

logic In an automatic data processing system, the systematic scheme that defines the interactions of the physical entities representing data.

lone pair of electrons A pair of unshared *valence electrons* that are responsible for the formation of coordinate bonds. See *valence*, *electronic theory of*. They occupy the same *orbital* but have opposite *spins*.

longitude The angle that the terrestrial *meridian* through the geographical poles and a point on the Earth's surface makes with a standard meridian (usually through Greenwich) is the longitude of the point. In astronomy, the 'celestial longitude' is the *angular distance* of a celestial body from the vernal *equinox* along the *ecliptic*, measured through 360° towards the East.

longitude, lines of Imaginary *meridians* on the Earth's surface, referred to a standard meridian; they are *great circles* of the Earth intersecting at the poles.

longitudinal Lengthwise; in a line with the length of the object under consideration.

longitudinal waves Waves in which the vibration or displacement takes place in the direction of propagation of the waves; e.g. *sound waves*. See also *transverse waves*.

long sight See *hypermetropia*; *presbyopia*.

Lorentz-Fitzgerald contraction A contraction in the length of a moving object, postulated by H. A. Lorentz and G. F. Fitzgerald (1851-1901) to account for the negative result of the *Michelson-Morley experiment*. The contraction is only appreciable at velocities comparable to the *velocity of light* and was given a theoretical explanation by Einstein in his special theory of *relativity*. In special relativity an

LORENTZ TRANSFORMATION

object at rest, of length l_0 , in one frame of reference, will appear to an observer in another frame of reference to have a length $l_0\sqrt{1-v^2/c^2}$, where v is the velocity of one frame of reference relative to the other and c is the velocity of light.

Lorentz transformation A set of equations for correlating space and time coordinates in two frames of reference, especially at relativistic velocities. Named after Hendrik Lorentz (1853-1928).

Loschmidt's constant The number of molecules per cubic centimetre of a perfect gas at S.T.P.; equal to $2.687\ 19 \times 10^{19}$ per cc.

loudness of sound The magnitude of the physiological response of the ear to sound. As the ear responds differently to different frequencies, the loudness of a sound will depend to a certain extent on its frequency. However, loudness can be roughly correlated with the cube root of the intensity of sound, and different levels can be conveniently compared by the units *decibel* and *phon*.

loudspeaker A device for converting electric currents into sounds loud enough to be heard at a distance. Commonest type consists of an electromagnetically vibrated paper cone.

Lovibond tintometer* A colorimeter in which the colour of a liquid, surface, powder, or light source is compared with a series of glass slides of standardized colours.

low frequency LF. A radio frequency in the range 30-300 kilohertz.

lumen The derived SI unit of luminous flux. The amount of light emitted per second in unit solid angle of one steradian by a uniform point source of one candela intensity; i.e. the amount of light falling per second on unit area placed at unit distance from such a source. Symbol lm.

luminance The luminous intensity of any surface in a given direction per unit of orthogonally projected area of that surface, on a plane perpendicular to the given direction. It is measured in candela per square metre.

luminescence The emission of light from a body from any cause other than high temperature. It is caused by the emission of photons when an excited atom returns to the ground state. Fluorescence and phosphorescence are particular cases of luminescence.

luminosity 1. The property of emitting light. 2. The amount of light emitted by a star, irrespective of its distance from the Earth, usually expressed as a magnitude.

luminous flux The luminous flux through an area is the amount of light passing through that area in one second. The derived SI unit of luminous flux is the lumen.

luminous intensity The amount of light emitted per second in unit solid angle by a point source, in a given direction. The SI unit of luminous intensity is the candela. The term is restricted to point sources.

- luminous paint** *Paint* prepared from phosphorescent compounds such as calcium sulphide, etc., which glows after exposure to light. See *phosphorescence*.
- lunar caustic** *Silver nitrate*. AgNO_3 ; usually fused and cast into sticks.
- lunation** Synodic month. The time between one new moon (see *phases of the moon*) and the next; equal to 29 days 12 hours and 44 minutes.
- lutetium** Cassiopeium. Lu. Element. A.W. 174.97. At. No. 71. R.d. 9.842, m.p.1652°C. See *lanthanides*.
- lux** Metre candle. The derived SI unit of illuminance; one lumen per square metre. Symbol lx.
- Lyddite** An explosive consisting of *picric acid* (trinitrophenol, $\text{C}_6\text{H}_2\text{OH}(\text{NO}_2)_3$), mixed with 10% *nitrobenzene* and 3% *Vaseline**.
- Lyman series** A series of lines that occurs in the *ultraviolet* region of the spectrum of hydrogen. Named after T. Lyman.
- lyophilic colloid** 'Solvent-loving colloid'. See *colloidal solutions*.
- lyophobic colloid** 'Solvent-hating colloid'. See *colloidal solutions*.
- lysergic acid** $\text{C}_{15}\text{H}_{15}\text{N}_2\text{COOH}$. A crystalline substance obtained from ergot and used in the manufacture of the hallucinogen LSD (lysergic acid diethylamide).
- lysine** An essential crystalline soluble amino acid, m.p. 224°C. See Appendix, Table 5.
- lysis** The dissolution or destruction of cells (especially blood cells or bacteria) by a class of antibodies called lysins.
- Lysol*** A mixture of the *cresols* with a solution of soft soap. Used as a disinfectant.

M

- machine** A device for overcoming resistance at one point by the application of a *force*, usually at some other point. It is generally understood to be any arrangement for the purpose of taking in some definite form of *energy*, modifying it and delivering it in a form more suitable for the desired purpose.
- machmeter** An instrument for measuring the speed of an aircraft relative to the speed of *sound*. See *Mach number*.
- Mach number** The ratio of the speed of a *fluid* or body to the local speed of *sound*. The speed of a fluid or body is therefore said to be *supersonic* if its Mach number is greater than unity. See also *hypersonic*. Named after Ernst Mach (1838-1916).
- macro-** Prefix denoting large, in contrast to *micro-*, small.
- macrocyclic** Containing a ring structure consisting of more than twelve *atoms* in the *molecule*.
- macromolecular** Consisting of or pertaining to *macromolecules*; having a very high *molecular weight*.
- macromolecule** A very large *molecule*, generally of a *polymer*. See *polymerization*.
- Magellanic clouds** Two small patches of *light* that appear, from the southern hemisphere, to be detached from the main bright band of *stars* constituting the *Milky Way*. These objects are separate *galaxies*, being two of the smaller members of the *Local Group* to which our *Galaxy* belongs. Named after Ferdinand Magellan (1480-1521).
- magenta** Fuchsine. $C_{20}H_{22}N_3OCl$. A red dye, prepared from *aniline* and *toluidine*.
- magic numbers** The numbers 2, 8, 20, 28, 50, 82, and 126. Atomic *nuclei* containing these numbers of *neutrons* or *protons* have exceptional stability.
- Magnadur*** A *ferrite* used for making permanent *magnets*.
- Magnalium*** A light *alloy*, r.d. 2-2.5; it consists of aluminium with from 5% to 30% magnesium.
- magnesia** See *magnesium oxide* or *magnesium hydroxide*; 'magnesia alba' of pharmacy is *basic magnesium carbonate*; 'fluid magnesia' is a *solution* of magnesium hydrogen carbonate.
- magnesite** Natural magnesium carbonate, $MgCO_3$, which occurs in white masses; used in the manufacture of *refractories* and *fertilizers*.
- magnesium** Mg. Element. A.W. 24.312. At. No. 12. A light, silvery-white *metal*, r.d. 1.74, m.p. $651^{\circ}C.$, that tarnishes easily in air. It burns with an intense white *flame* to form *magnesium oxide*, MgO . Magnesium occurs as *magnesite*, $MgCO_3$; *dolomite*,

- $\text{MgCO}_3 \cdot \text{CaCO}_3$; *carnallite*, $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, and in many other compounds; it is prepared by electrolysis of fused *carnallite*. Used in lightweight alloys, in photography and incendiary bombs. Compounds are used in medicine. It is essential to life as it occurs in *chlorophyll*.
- magnesium chloride** MgCl_2 . A white *deliquescent* substance, m.p. 708°C ., that occurs in sea-water and also as *carnallite*. A concentrated solution mixed to a paste with *magnesium oxide* sets to a stone-like mass owing to the formation of the oxychloride, Mg_2OCl_2 (*Sorel's cement*).
- magnesium hydroxide** *Magnesia*, $\text{Mg}(\text{OH})_2$. A white crystalline substance, used as an *antacid* in 'milk of *magnesia*'.
- magnesium oxide** *Magnesia*, MgO . A white tasteless substance, m.p. 2800°C ., used as an *antacid* and a laxative.
- magnesium sulphate** *Epsom salts*, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. A white crystalline soluble salt, used in medicine and in leather processing.
- magnesium trisilicate** *Dimagnesium trisilicate*, $2\text{MgO} \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O}$. A white tasteless powder used as an *antacid* and to absorb odours.
- magnesothermic reduction** *Reduction of oxides* to the corresponding metals at high temperatures with the aid of metallic *magnesium*. It is analogous to *aluminothermic reduction*.
- magnet, permanent** A *ferromagnetic substance* that has a permanent magnetic field and magnetic moment associated with it. See also *magnetic domains*.
- magnetic amplifier** A device for the amplification of small direct currents and of low frequency alternating currents. It depends upon the fact that the output from the secondary coil of a transformer due to an alternating current in the primary coil is also a function of a direct current (the signal to be amplified) in a third winding on the transformer core.
- magnetic bottle** Any configuration of magnetic fields used in the containment of a plasma during controlled thermonuclear reaction experiments.
- magnetic circuit** A closed path following the lines of force of a magnetic field.
- magnetic constant** Permeability of free space, μ_0 . The fundamental constant that has the value $4\pi \times 10^{-7}$ henry per metre. It arises as the constant of proportionality in *Ampere's law*, its value depending on the choice of units. See also *magnetic permeability*.
- magnetic declination** Magnetic variation, variation of the compass. The angle between the planes of the geographic and magnetic meridian. See *magnetism, terrestrial*.
- magnetic dip** Angle of dip, inclination. The angle between the direction of the Earth's magnetic field (see *magnetism, terrestrial*) and the horizontal; i.e. the angle through which a magnetic needle will 'dip'

MAGNETIC DIPOLE

from the horizontal when suspended free to swing in a vertical plane in the *magnetic meridian*. See *dip circle*; *magnetic equator*.

magnetic dipole See *dipole*; *magnetic moment*.

magnetic domains The fact that *ferromagnetic* substances are not necessarily always magnetized led to the theory that they consist of separate domains, each of which is spontaneously magnetized, but the *magnetic moments* of which may not be aligned. If an external *magnetic field* is applied to the substance the magnetic moments of the domains (not the domains themselves) are rotated so that they lie parallel to the field; the substance then acts as a permanent *magnet*.

magnetic drum A cylinder coated with magnetic material for storing information in a *computer*, especially in the *backing storage*. The information is stored in the magnetic coating in the form of magnetic *dipoles*, the orientation or polarity of which can be used to indicate one of the digits in a *binary notation*.

magnetic elements The three quantities, *magnetic declination*, angle of dip (see *magnetic dip*), and *horizontal component*, which define completely the Earth's magnetic field (see *magnetism*, *terrestrial*) at any point.

magnetic equator Aclinic line. A line of zero *magnetic dip* lying fairly near the geographical *equator*, but passing North of it in Africa and the Indian Ocean, and South of it in America and the Eastern Pacific.

magnetic field A *field of force* that is said to exist at any point if a small coil of wire carrying an *electric current* experiences a *couple* when placed at that point. A magnetic field may exist at a point as a result of the presence of either a permanent *magnet* or a circuit carrying an *electric current*, in the neighbourhood of the point.

magnetic field of electric current A wire or coil carrying an *electric current* is surrounded by a *magnetic field*. The direction of the field relative to the current may be determined by the following corkscrew rule: If a corkscrew, held in the right hand, is turned along the conductor in the direction of the current, the movement of the thumb indicates the direction of the magnetic field produced. The strength of the magnetic field at the centre of a circular coil of wire of radius r , consisting of n turns, in which a current of I amperes is flowing, is $nI/2\pi r$ amperes per metre in SI units or $2\pi nI/10r$ oersted in c.g.s. units.

magnetic field strength H . The strength of a magnetic field measured in amperes per metre (SI units) or oersteds (c.g.s. units). It is given by $H = B/\mu_0 - M$, where B is the *magnetic flux density*, M is the *magnetization*, and μ_0 is the *magnetic constant*. See *magnetic field of an electric current*.

magnetic flux Φ . The product of a given area and the component of the *magnetic field strength* at right angles to that area. The c.g.s. unit

of magnetic flux is the *maxwell*. The derived *SI unit* of magnetic flux is the *weber*.

magnetic flux density Magnetic induction. *B*. The *magnetic flux* passing through unit area of a *magnetic field* in a direction at right angles to the *magnetic force*. The derived *SI unit* of magnetic flux density is the *tesla* (*weber per square metre*). The *c.g.s. unit* is the *gauss*.

magnetic force The attractive or repulsive *force* exerted by a *magnetic field* on a *magnetic pole* or an *electric charge*.

magnetic induction 1. The induction of *magnetism* in a body by an external *magnetic field*. 2. See *magnetic flux density*.

magnetic iron ore See *magnetite*.

magnetic line of force A line whose direction at each point is that of the *magnetic field* at that point; the path along which a free *magnetic pole* would travel.

magnetic meridian See *magnetism, terrestrial*.

magnetic mirrors The regions of high field strength at the end of an externally generated *magnetic field* used in the *containment* of a *plasma* in controlled *thermonuclear reaction* experiments. *Ions* that enter these regions of high field strength reverse their direction of motion (are reflected) and return to the central region of the *plasma* in which they become trapped.

magnetic moment 1. The torque experienced by a magnetic *dipole* in a field of unit *magnetic field strength*. It is measured in *weber metres*. This is also called the magnetic dipole moment. 2. The product IA , where I is the current flowing through a small loop of wire of area A . It is measured in *ampere metres squared* ($A\ m^2$). This is also called the electromagnetic moment.

magnetic monopole A hypothetical unit of magnetic 'charge' analogous to *electric charge*. No evidence has been found for the existence of a separate *magnetic pole*, they are always found in pairs.

magnetic permeability μ . The ratio of the *magnetic flux density* in a medium to the external *magnetic field strength* that induces it. The 'relative permeability', μ_r , is the ratio of the permeability of a substance to the permeability of free space (see *magnetic constant*). For most substances μ_r has a constant small value. When μ_r is less than 1, the material is said to be *diamagnetic*; if μ_r is greater than 1, it is *paramagnetic*. A few substances, notably iron, have very large values of μ , which tend to fall as the field strength increases so that the magnetic flux density tends to a limiting value called the saturation value. Such substances are said to be *ferromagnetic*.

magnetic pole A *magnet* appears to have its *magnetism* concentrated at two points termed the poles. If a bar magnet is suspended to swing freely, one of these, the North-seeking, North, or positive pole, will point North, and the other South. Unlike poles attract, and like poles repel each other. The *force* of attraction or repulsion between

MAGNETIC POTENTIAL

two poles varies inversely as the *square* of the distance between them (see *inverse square law*). The strength of a magnetic pole was formerly expressed in terms of a 'unit magnetic pole', to which the inverse square law was applied. Thus, the force between two poles m_1 and m_2 , separated by a distance d in a vacuum, was given by $m_1 m_2 / d^2$. In modern practice the magnetic dipole moment is used (see *magnet moment*; *dipole*).

magnetic potential See *magnetomotive force*.

magnetic storm A sudden disturbance in the Earth's magnetic field (see *magnetism, terrestrial*) associated with *sunspot* activity, which affects *compasses* and *radio* transmission.

magnetic susceptibility χ_m . The ratio of the *magnetization* (M) produced in a substance to the *magnetic field strength* (H) to which it is subjected, i.e. $\chi_m = M/H$. The susceptibility is related to the relative permeability, μ_r , (see *magnetic permeability*) by $\chi_m = 1 - \mu_r$. Ferromagnetic materials have high positive values of χ_m .

magnetic tape Plastic tape coated with a *ferromagnetic* powder, used in tape recorders. The tape is passed over the gap in a *magnetic circuit*, which is modulated in accordance with information to be recorded. The tape retains a record of the *modulation*, which can be 'played back' through a suitable circuit. Magnetic tape is used in the *backing storage* of computers.

magnetic variation See *magnetic declination*.

magnetism The branch of physics concerned with *magnets* and *magnetic fields*. See *diamagnetism*; *paramagnetism*; *ferromagnetism*; *ferromagnetism*.

magnetism, terrestrial Geomagnetism. The Earth's magnetism. The Earth possesses a *magnetic field*, the strength of which varies with time and locality. The field is similar to that which would be produced by a powerful *magnet* situated at the centre of the Earth and pointing approximately North and South. A magnetized needle suspended to swing freely in all planes will set itself pointing to the Earth's magnetic North and South poles, at an angle to the horizontal (see *magnetic dip*). The vertical plane through the *axis* of such a needle is termed the *magnetic meridian*, defined as the vertical plane that contains the direction of the Earth's magnetic field. At any point on the Earth's surface, terrestrial magnetism is defined by the three *magnetic elements*: the horizontal component B_0 of the *magnetic flux density* at that point; the angle of dip (the angle between B_0 and the resultant magnetic flux density); and the declination (the angle between B_0 and the geographic true north. See *magnetic declination*).

The cause of the Earth's magnetism is not definitely known. The variations of the Earth's magnetic field with time are of two types, the 'secular' and the 'diurnal'. The secular variations are slow changes in the same sense, but at different rates, as a result of which

the Earth's magnetic field has decreased by some 5% over the last hundred years. The cause of these variations is unknown. The diurnal variations are much smaller and more rapid variations which have been shown to be associated with changes in the ionosphere related to sunspot activity.

magnetite Magnetic iron ore. Natural black oxide of iron, Fe_3O_4 .

magnetization M . The magnetic moment per unit volume of a magnetized body. It is equal to $B/\mu_0 - H$, where B is the magnetic flux, μ_0 is the magnetic constant, and H is the magnetic field strength.

magnet A small dynamo provided with a spark-coil, for ignition of petrol vapour in petrol internal-combustion engines.

magnetohydrodynamics MHD. 1. The study of the behaviour of moving electrically conducting fluids in magnetic fields. 2. A method of generating electricity by subjecting the free electrons in a high velocity flame or plasma to a strong magnetic field. The free-electron concentration in the flame is increased by the thermal ionization of added substances of low ionization potential (e.g. containing sodium or potassium). These electrons constitute a current when they flow between electrodes within the flame, under the influence of the external magnetic field.

magnetometer An instrument for comparing strengths of magnetic fields, and magnetic moments. It consists of a short magnet with a long, non-magnetic pointer at right angles across it, pivoted at the junction. The pointer swings along a circular scale, thus enabling deflections of the short magnet to be measured.

magnetomotive force MMF. Formerly called the magnetic potential. A quantity analogous to the electromotive force. It is defined as the circular integral of the magnetic field strength around a closed path.

magneton A unit for measuring the magnetic moments of atomic particles. The Bohr magneton, μ_B , is equal to

$$eh/4\pi m_e = 9.2741 \times 10^{-24} \text{ ampere metre}^2$$

where e and m_e are the charge and mass of the electron and h is Planck's constant. The nuclear magneton, μ_N , is equal to

$$\mu_B \cdot m_e/m_p = 5.05 \times 10^{-27} \text{ ampere metre}^2$$

where m_p is the mass of the proton. The symbols m_B and m_N are sometimes used for the Bohr magneton and the nuclear magneton respectively.

magnetosphere The space surrounding the Earth, or any celestial body, in which there is a magnetic field associated with that body.

magnetostriction A change in the dimensions of ferromagnetic substances on magnetization.

magnetron A thermionic valve capable of producing high power oscillations in the microwave region. It consists of a heater, a

MAGNIFICATION

central *cathode*, and an *anode* with a number of radial segments, all enclosed in an evacuated container, which is situated in the gap of an external *magnet*. The movement of the *electrons* is controlled by a combination of crossed *electric* and *magnetic fields*. Used extensively in *radar*.

magnification (Of a *microscope* or other optical instrument). The ratio of the linear dimensions of the final image to the linear dimensions of the object.

magnifying glass A *convex lens*. See *microscope, simple*.

magnifying power of a compound microscope The ratio of the *angle* subtended at the eye by the final image to the angle subtended by the object placed at the least distance of distinct vision (i.e. the shortest distance from the eye at which the object can be seen distinctly).

magnifying power of a lens The ratio of the *angle* subtended at the eye by the *virtual image* to the angle subtended by the object when placed at the least distance of distinct vision; this latter is generally taken to be 0.25 metres.

magnitude of stars The apparent magnitude is a measure of the relative apparent *brightness of stars*. A star of any one magnitude is approximately 2.51 times brighter than a star of the next magnitude. E.g. a star of the first magnitude is $(2.51)^3$ times as bright as a star of the fourth magnitude. The absolute magnitude is defined as the apparent magnitude a given star would have at the standard distance of 10 *parsecs*.

magnox A magnesium alloy used for sheathing uranium *fuel elements* in certain types of *nuclear reactor*. See *gas-cooled reactor*.

main sequence stars See *Hertzprung-Russell diagram*.

major axis The *axis* of an *ellipse* that passes through both *foci*. See Fig. 15, under *ellipse*.

majority carriers In a *semiconductor*, the type of *carrier* that constitutes more than half the total number of carriers.

Maksutov telescope An astronomical telescope developed by D. D. Maksutov in 1944. It consists of a *concave spherical mirror* the *aberration* of which is reduced by a *meniscus lens*.

malachite Natural *basic copper carbonate*, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$. A bright green *mineral*.

malate A *salt* or *ester* of *malic acid*.

maleate A *salt* or *ester* of *maleic acid*.

maleic acid $\text{HOOCCH}:\text{CHCOOH}$. A colourless crystalline *soluble unsaturated acid*, m.p. 137°C ., *isomeric* with *fumaric acid*. Used in the manufacture of synthetic *resins*, *dyes*, and as a *preservative*.

malic acid Hydroxysuccinic acid. $\text{COOH} \cdot \text{CH}_2 \cdot \text{CH}(\text{OH}) \cdot \text{COOH}$. A white crystalline *organic acid*, m.p. $98^\circ\text{--}99^\circ\text{C}$. It occurs in unripe apples and other fruits.

malleability The ability to be hammered out into thin sheets.

malonic acid $\text{CH}_2(\text{COOH})_2$. A white crystalline *soluble dibasic acid*, m.p. 135.6°C ., used in the manufacture of *barbiturates*.

malonyl The *bivalent radical* $-\text{OCCH}_2\text{CO}-$, derived from *malonic acid*.

malonylurea See *barbituric acid*.

malt Grain (usually barley) that has been allowed to germinate and then heated and dried. See *brewing*.

maltase An *enzyme* occurring in *yeast* and other *organisms* that hydrolyzes (see *hydrolysis*) *maltose* into *glucose*.

maltose Malt sugar, maltobiose. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A hard crystalline *soluble disaccharide*, less sweet than *cane-sugar*. It is formed in *malt* by the action of the *enzyme diastase* on *starch*.

malt sugar See *maltose*.

mandelic acid $\text{C}_6\text{H}_5\text{CHOHCOOH}$. A white crystalline *optically active* substance, the *racemic form* of which has m.p. 120.5°C .; used as an *antiseptic*.

manganate A *salt* of *manganic acid*.

manganese Mn. Element. A.W. 54.938. At. No. 25. A reddish-white, hard brittle *metal*, r.d. 7.20, m.p. 1244°C . It occurs as *pyrolusite*, MnO_2 , from which it is extracted by *reduction* with carbon or aluminium. Used in numerous *alloys*.

manganese bronze Manganese brass. A copper-zinc *alloy* containing up to 4% manganese.

manganese dioxide Manganese peroxide, MnO_2 . A heavy, black powder that occurs naturally as *pyrolusite*. Used as a source of manganese metal, as an *oxidizing agent*, in *glass* manufacture, in *Leclanché cells*, as a *catalyst* in the laboratory preparation of oxygen, etc.

manganese steel A very hard variety of *steel* containing up to 13% manganese.

manganic acid H_2MnO_4 . A hypothetical *acid* that exists only in *solution* or in the form of its *salts*, the *manganates*.

manganin An *alloy* containing 83% copper, 13% manganese, 4% nickel. As its electrical *resistance* is affected only slightly by change in *temperature* it is used for resistance coils.

mannitol $\text{HOCH}_2(\text{CHOH})_4\text{CH}_2\text{OH}$. A white crystalline *optically active polyhydric alcohol*, the *racemic form* of which has m.p. 168°C .; used in the manufacture of synthetic *resins* and *plasticizers*.

mannitol hexanitrate $\text{C}_6\text{H}_8(\text{ONO}_2)_6$. A colourless *insoluble* substance, m.p. 112°C ., used as an *explosive* and in medicine.

manometer Any instrument used for measuring gaseous *pressure*.

mantissa The decimal, always positive, portion of a common *logarithm*.

marble A form of natural *calcium carbonate*, CaCO_3 .

margarine A butter substitute prepared from purified vegetable and animal *fats* and *oils*. Milk is added to a suitable blend of fats;

bacterial action in the milk produces a butter-like flavour; vitamins A and D (see *vitamins*) and suitable colouring materials are added.

Markownikoff (Markovnikov) rule In the addition of a hydrogen *halide* to an asymmetric *alkene*, the *halogen atom* becomes attached to the carbon atom with the fewer hydrogen atoms. Named after V. V. Markovnikov (1838-1904).

Mars (astr.) A *planet*, with two small *satellites*, having its *orbit* between those of the *Earth* and *Jupiter*. Mean distance from the *Sun* 227.94 million kilometres. *Sidereal period* ('year') = 686.98 days. Mass 0.107 that of the Earth, diameter 6790 kilometres. The atmosphere, composed mainly of *carbon dioxide*, has a pressure of only about 0.01 atmosphere. The polar ice caps are solid carbon dioxide. The day temperature at the equator is about $-40^{\circ}\text{C}.$, dropping to about $-70^{\circ}\text{C}.$ at night.

marsh gas See *methane*, CH_4 .

Marsh's test A sensitive test for arsenic that depends upon the formation of *arsine* when arsenic or its *compounds* are present in a *solution* evolving hydrogen. When the arsine is passed through a narrow, heated tube it is decomposed and leaves a deposit of metallic arsenic.

martensite The hard and brittle constituent of *steel* produced when the material is cooled from its hardening *temperature* at a greater rate than its critical cooling rate.

mascon A local concentration of high *mass*, below the surface of the *Moon*, of unexplained origin.

maser Microwave Amplification by Stimulated Emission of Radiation. A class of *amplifiers* and *oscillators* that makes use of the internal *energy* of *atoms* and *molecules* to obtain low noise-level amplification and *microwave* oscillations of precisely determined *frequencies*. Stimulated emission, which is the basic principle on which these devices work, is the emission by an *atom* in an excited *quantum state* (see *excitation*) of a *photon*, as the result of the impact of a photon from outside of exactly equal energy. Thus the stimulating photon, or wave, is augmented by the one emitted by the excited atom. A maser consists of an 'active medium' (either in the gaseous or *solid state*), in which most of the atoms can be optically pumped to an excited state by subjecting the system to *electromagnetic radiation* of different frequencies to that of the stimulating frequency (see *population inversion*). The active medium is enclosed in a *resonant cavity* so that a wave is built up with only one mode of oscillation, which is equivalent to a single output frequency. Masers can also be made to operate at optical frequencies, when they are referred to as optical masers or *lasers*.

mass *m*. A characteristic of a material body that can be defined in either of two ways. The *inertial mass* of a body is the constant of proportionality in the relationship $F \propto a$, where *a* is the acceleration

produced when the body is acted on by a force F . The gravitational mass is determined by Newton's law of *gravitation*. It is the gravitational mass that is used in measuring *weight* and in defining the *kilogram*, the unit of mass. In fact the inertial mass is equal to the gravitational mass. See also *rest mass*; *relativistic mass*; *mass-energy equation*.

mass action law The velocity of a chemical change is proportional to the *active masses* (*molecular concentrations*) of the reacting substances.

mass decrement The difference between the *isotopic weight* of an *isotope* and its *mass number*.

mass defect The difference between the *mass* of a *nucleus* and the sum of the masses of its constituent *nucleons*. The *energy* equivalent of the mass defect, on the basis of the *mass-energy equation*, must be supplied to a nucleus to split it into its component nucleons.

mass-energy equation Mass and energy are mutually convertible under certain conditions. The equation connecting the two quantities in any such transformation is $E = mc^2$, where c is the velocity of *light* in m s^{-1} and E is the energy, in *joules*, released when a mass m , in *kilograms*, is completely converted into energy. In *c.g.s. units*, if m is in *grams* and c is in cm s^{-1} , E will be in *ergs*. See *annihilation radiation*; *conservation of mass and energy*.

massicot A yellow powder consisting of unfused *lead monoxide*, PbO .

mass number Nucleon number. A . The *integer* nearest to the *atomic mass* of an *isotope*, i.e. the number of *nucleons* in the *nucleus* of an *atom*.

mass spectrograph An apparatus for the determination of the exact *masses* of individual *atoms*, i.e. *isotopic weights*, by photographing the *mass spectrum* produced.

mass spectrometer An apparatus for obtaining the *mass spectrum* of a *beam* of *ions* by means of suitably disposed *magnetic* and *electric fields*. The deflection of any individual ion in these fields depends on the ratio of its *mass* to its *electric charge*, m/e . Such a spectrum will appear as a number of lines on a photographic plate, each corresponding to a definite value of m/e . *Isotopes* were first discovered in this way. The method was formerly known as 'positive ray analysis'.

mass spectrum A *spectrum* obtained with a *mass spectrometer* or *spectrograph* in which a *beam* of *ions* is arranged in order of increasing *charge* to *mass* ratio.

masurium Former name of *element* of At. No. 43; replaced in 1949 by the name *technetium*.

matches The heads of safety matches usually contain *antimony trisulphide*, *oxidizing agents* such as *potassium chlorate*, and some sulphur or *charcoal*; while the striking surface contains red

MATRIX

phosphorus. Ordinary non-safety match-heads contain phosphorus sulphide, P_4S_3 ; very rarely red phosphorus.

matrix 1. A mould for shaping a cast. 2. (math.) An arrangement of mathematical elements into rows and columns according to algebraic rules, in order to solve a set of *linear* equations. 3. (computers) An array of components for translating from one code to another. 4. (metallurgy) The crystalline *phase* in an *alloy*, in which the other phases are contained.

matte A mixture of the *sulphides* of iron and copper obtained as an intermediate stage in the *smelting* of copper.

matter A specialized form of *energy* that has the attributes of *mass* and extension in *space* and time.

mauve Mauveine, aniline violet. A reddish-violet *dye*; a complex *organic compound*, the first organic dye to be prepared artificially.

maximum (math.) A function $y = f(x)$ has a maximum value at $x = a$ if $f(a)$ is greater than the values of the function immediately preceding and immediately following $x = a$. The function has a minimum value at $x = b$ if $f(b)$ is less than the value of the function immediately preceding and immediately following $x = b$.

maximum and minimum thermometer See *thermometer*.

maximum permissible dose (or level) See *dose*.

Maxwell The *c.g.s. unit of magnetic flux*. The flux through 1 square centimetre normal to a magnetic field of strength 1 gauss. 1 maxwell = 10^{-8} weber. Named after James Clerk Maxwell (1831-79).

Maxwell-Boltzmann distribution A statistical *equation* giving the distribution of *velocities* or positions of the *molecules* in a *gas*; it is based on the assumptions that all the particles are indistinguishable and each has an equal *probability* of appearing in a particular region. Named after James Clerk Maxwell (1831-79) and Ludwig Boltzmann (1844-1906).

mean (math.) 1. The average of a set of values; arithmetic mean. 2. See *geometric mean*.

mean free path The average, or *mean*, distance travelled by a particle, *atom*, or *molecule* between collisions. In a *gas*, the mean free path between molecules is inversely proportional to the *pressure*. See *kinetic theory of gases*.

mean free time The average, or *mean*, time that elapses between two collisions of a particle, *atom*, or *molecule*.

mean solar day See *solar day*.

mechanical advantage In a *machine*, the ratio of the actual load raised to the *force* required to maintain the machine at constant speed.

mechanical equivalent of heat If H units of *heat* are completely converted into W units of *work* then $W = JH$, where J is a constant called the mechanical equivalent of heat, or Joule's equivalent. J represents the amount of work obtainable by the

complete conversion of unit quantity of heat into mechanical work. 1 *calorie* (15°) = 4.185×10^7 *ergs*; 1 *British Thermal Unit* = 778 ft lb; i.e. *J* has the values of 4.185×10^7 *ergs/calorie* and 778 ft lb/Btu respectively for these two sets of units. In *SI units*, *W* and *H* would both be measured in *joules*, and *J* would therefore equal 1.

mechanics The branch of physical science dealing with the behaviour of *matter* under the action of *force*. See *dynamics*; *statistics*; *kinematics*.

mechanistic theory The view that all biological phenomena may be explained in mechanical, physical, and chemical terms; in opposition to the *vitalistic theory*.

median 1. A line joining a vertex of a *triangle* to the mid-point of the opposite side. 2. The middle number in a sequence of numbers.

median lethal dose (M)LD₅₀ The dose of *ionizing radiation* that would kill 50% of a large batch of *organisms* within a specified period.

medium frequencies M.F. *Radio frequencies* in the range 300-3000 *kilohertz*.

meerschau Natural *hydrated magnesium silicate*, $\text{Mg}_2\text{Si}_3\text{O}_8 \cdot 2\text{H}_2\text{O}$. It is a white *solid* used for tobacco pipes.

mega- Prefix denoting one million times, in *metric units*; symbol M. More loosely, denoting 'very large'.

megahertz MHz. 1 million *hertz*. A measure of *frequency* equal to 10^6 *cycles per second*.

megaton bomb A *nuclear weapon* with an explosive power equivalent to one million tons of *T.N.T.* (approximately 4×10^{15} *joules*).

megohm One million *ohms*.

melamine $\text{C}_3\text{H}_6\text{N}_6$. Triaminotriazine. A white crystalline substance, m.p. 354°C ., that forms a *thermosetting resin* with *formaldehyde*.

melanin $\text{C}_{17}\text{H}_{98}\text{O}_{33}\text{N}_{14}\text{S}$. A dark brown pigment produced in the skin cells called melanocytes. Skin and hair colours in many animals, including man, are due to melanin. People of different races have approximately the same number of melanocytes, colour differences being due to variations in the distribution of melanin in the skin. The *Sun* stimulates the production of melanin in melanocytes, and the function of the melanin is to absorb the *Sun's* harmful radiations.

melting point The constant *temperature* at which the *solid* and *liquid phase* of a substance are in equilibrium at a given *pressure*. Melting points are normally quoted for standard atmospheric pressure.

Mendeleev's law See *periodic law*. Named after Dimitri Ivanovich Mendeleev (1834-1907).

mendelevium Md. *Transuranic element*, At. No. 101. The most stable isotope, $^{258}_{101}\text{Md}$, has a *half-life* of 60 days.

meniscus 1. The curved surface of a *liquid* in a vessel. If the *contact angle* between the liquid and the wall of the vessel is less than 90° ,

MENSURATION

- the meniscus is *concave*; if greater, the meniscus is *convex*. 2. A *concavo-convex lens*. See Fig. 24, under *lens*.
- mensuration** The measurement of lengths, areas, and volumes.
- menthol** $C_{10}H_{20}O$. One of a series of *organic compounds* of the *camphor* group. A white crystalline substance that occurs in natural oils, m.p. $42^{\circ}C$., with a characteristic smell. Used in medicine.
- mercaptans** See *thiols*.
- mercaptide** See *thiolates*.
- mercuric** A compound of *bivalent* mercury.
- mercuric chloride** Corrosive sublimate. $HgCl_2$. A poisonous white crystalline *soluble salt*, m.p. $276^{\circ}C$., used as an *antiseptic*.
- mercuric fulminate** Fulminate of mercury, mercuric isocyanate. $Hg(ONC)_2$. A white crystalline substance that explodes on being struck; used in detonators to initiate *explosions*.
- mercuric oxide** HgO . A *soluble* poisonous powder that occurs as yellow or red *crystals*; used as a *pigment* and an *antiseptic*.
- mercuric sulphide** HgS . An *insoluble* substance that occurs naturally as *cinnabar*. The pure compound consists of a red powder, m.p. $583.5^{\circ}C$., and is used as a *pigment*.
- mercurous** A compound of *univalent* mercury.
- mercurous chloride** Calomel. Hg_2Cl_2 . A white *insoluble* powder used in medicine and as a *fungicide*.
- Mercury** (astr.) A *planet* with its orbit nearest the *Sun*. Mean distance from the Sun 57.91 million kilometers. Sidereal period ('year') = 87.969 days. Mass 0.054 that of the *Earth*, diameter 4840 kilometres. It has no atmosphere and a day temperature of about $400^{\circ}C$.
- mercury** Quicksilver, Hydrargyrum. Hg . Element. A.W. 200.59. At. No. 80. A *liquid*, silvery-white *metal*, r.d. 13.6, m.p. $-39^{\circ}C$., b.p. $357^{\circ}C$., which occurs as *cinnabar*, HgS . It is extracted by roasting the ore in a current of air. Used in *thermometers*, *barometers*, *manometers*, and other scientific apparatus; *alloys* (called *amalgams*) are used in dentistry. *Compounds* are poisonous; some are used in medicine.
- mercury cell** A *primary cell* consisting of a zinc anode, a cathode of mercuric oxide (HgO) mixed with *graphite* (about 5%), and an electrolyte of *potassium hydroxide* (KOH) saturated with *zinc oxide* (ZnO). The *E.M.F.* is about 1.3 *volts* and by suitable design the cell can be made to deliver about 0.3 *ampere-hour* per cm^3 .
- mercury vapour lamp** A lamp emitting a strong bluish *light* by the passage of an *electric current* through mercury vapour in a bulb. The light is rich in *ultraviolet radiations*; used in artificial sun-ray treatment and in street lighting. See also *fluorescent lamp*.
- meridian, celestial** The *great circle* of the *celestial sphere* passing through the *zenith* and the celestial poles, meeting the horizon at points called the North and South points.

meridian, magnetic See *magnetic meridian*.

meridian, terrestrial Meridian of longitude. An imaginary *great circle* drawn round the *Earth* that passes through both poles.

mescaline $C_{11}H_{17}NO_3$. A white *soluble* crystalline powder, m.p. $35-6^{\circ}C$., obtained from the mescal cactus and used as a hallucinogen.

mesitylene $C_6H_3(CH_3)_3$. 1,3,5-trimethylbenzene. A colourless *aromatic liquid hydrocarbon*, b.p. $164.7^{\circ}C$., that occurs in *coal-tar* and is used in organic synthesis.

mesityl oxide $(CH_3)_2C:CHCOCH_3$. A colourless oily *liquid*, b.p. $130^{\circ}C$., used as a *solvent* and in organic synthesis.

meso- A prefix indicating that a substance is optically inactive due to intra-molecular compensation.

mesomerism See *resonance*.

mesons A group of unstable *elementary particles* belonging to the class called *hadrons*. They are believed to consist of a *quark* and its antiquark. See also *psi particle*; *charm*. Positive, negative, and neutral mesons exist; when charged the magnitude of the charge is equal to that of the electron. Mesons are found in *cosmic rays* and are emitted by *nuclei* under bombardment by high *energy* particles. They are believed to play a vital part in the cohesion of *nucleons* within nuclei, but no satisfactory explanation of the *exchange forces* with which they are associated has yet been given. *Muons* were originally called μ -mesons, but they are now classified as *leptons* rather than mesons. See Appendix, Table 6.

mesophases Phases intermediate between crystalline and liquid phases (see *liquid crystals*; *cybotaxis*). Three different types are recognized: *smectic*, *nematic*, and *cholesteric crystals*, in accordance with the different arrangements of the *molecules* in them.

mesosphere 1. The region of the *Earth's atmosphere* between the *ionosphere* and the *exosphere*, extending from about 400 kilometres to 1000 kilometres above the *Earth's surface*. It is sometimes considered to be part of the *exosphere*. 2. The region of the *Earth's atmosphere* between the *stratosphere* and the *thermosphere*, extending from some 40 kilometres to 80 kilometres above the *Earth's surface*.

mesyl Methylsulphonyl. The *univalent radical* CH_3SO_2- .

meta 1. Denoting positions separated by one atom in a hexagonal ring of atoms, particularly the *benzene ring*. Abbreviated to *m-* as a prefix in naming a compound; e.g. *m*-dichlorobenzene (alternatively, 1,3-dichlorobenzene). Compare *ortho*; *para*. 2. A prefix indicating an *inorganic acid* (or a corresponding *salt*) of a lower degree of hydration; e.g. *metaphosphoric acid*, HPO_3 , as compared with *orthophosphoric acid*, H_3PO_4 .

metabolism The chemical processes associated with living *organisms*. It is usually divided into two parts: *catabolism*, as a result of which

METABOLITE

complex substances are decomposed into simple ones, with the release of *energy*, which becomes available for the organism's activities; and *anabolism*, which comprises the building up of complex substances with the absorption or storage of energy. Metabolic reactions are usually under the control of *enzymes*, which are consequently of immense importance in the chemistry of life. Metabolic processes are very similar throughout the plant and animal kingdoms and there are therefore corresponding similarities between the enzymes manufactured by organisms.

metabolite Any substance that takes part in the process of *metabolism*.

metal A substance having a 'metallic' lustre and being malleable, ductile, of high *relative density*, and a good *conductor* of *heat* and *electricity*. *Elements* having such physical properties to a greater or less degree are generally *electropositive* and combine with oxygen to give *bases*; their *chlorides* are stable towards *water*. A number of elements normally regarded as metals have only some of the above properties. See *metalloid*.

metalddehyde Meta. A white, *volatile*, inflammable poisonous solid *polymer* of *acetaldehyde*, CH_3CHO . Used as *fuel* in small heaters.

metallic crystals The type of *crystal* formed by most *metals*, in which the outer *electrons* of the metallic *atoms* are shared by the crystal as a whole. Thus, the positively charged metal *ions* in the crystal *lattice* are surrounded by a 'gas' of *free electrons*. These free electrons account for the fact that most metals are good *conductors* of *heat* and *electricity*.

metallic soap An *insoluble salt* formed by a *metal* and a *fatty acid* (especially salts of lead and aluminium). Used for waterproofing textiles and as a drier for *paints*.

metallography The study of the crystalline structure of *metals* and *alloys*.

metalloid An obsolescent term for an *element* having some properties characteristic of *metals* and others of non-metals. An element giving rise to an *amphoteric oxide* (e.g. *arsenic* or *antimony*). The terms 'semi-metal' or 'semi-metallic element' have been proposed as alternatives.

metallurgy The science and technology of *metals*; in particular, the extraction of metals from their *ores*, their heat treatment, and the compounding of *alloys*.

metamerism A type of *isomerism* exhibited by *organic compounds* of the same chemical class or type; it is caused by the attachment of different *radicals* to the same central *atom* or group. E.g. diethyl ether (C_2H_5)₂O, and methyl propyl ether, $\text{CH}_3\text{OC}_3\text{H}_7$.

metamorphism The transformation of the structure or constitution of rocks due to such natural factors as *heat* and *pressure*.

metaphosphoric acid HPO_3 . An *acid* derived from *phosphorus pentoxide*, consisting of a colourless *deliquescent solid*.

metastable state (chem.) The state of supercooled water (see *supercooling*) or of supersaturated solutions (see *supersaturation*) in which the *phase* that is normally *stable* under the given conditions does not form unless a small amount of the normally stable phase is already present. Thus supercooled water will remain as *liquid* water below 0°C. until a small *crystal* of ice is introduced.

metastable state (phys.) An excited state (see *excitation*) of an *atom* or *nucleus* that has an appreciable life-time.

metathesis (chem.) See *double decomposition*.

meteor A *solid* body from outer *space*. A meteor becomes incandescent ('shooting star') on entering the Earth's atmosphere owing to the frictional forces set up at its surface. Small meteors burn up completely in the atmosphere, but some of the larger ones survive and fall to Earth as meteorites. Meteorites are of two kinds, those that are predominantly stone and those predominantly iron. The largest meteorites can weigh up to 100 tons. Every day some million meteors enter the Earth's atmosphere and some 10 tons of meteorite material are added to the planet's surface.

meteorite See *meteor*.

meteorology The science of the weather; the study of such conditions as atmospheric *pressure*, *temperature*, *wind* strength, *humidity*, etc., from which conclusions as to the forthcoming weather are drawn.

meteor showers Exceptionally heavy falls of *meteors* (about 20 times greater than the average) that enter the Earth's *atmosphere* when the Earth's *orbit* crosses the orbit of a *comet*, i.e. an orbit that contains either the material of which comets are made or into which they disintegrate.

-meter Suffix denoting measurer; e.g. *voltmeter*.

methacrylate A *salt* or *ester* of *methacrylic acid*.

methacrylic acid $\text{CH}_2\text{C}(\text{CH}_3)\text{COOH}$. A corrosive *liquid*, m.p. 15°C., b.p. 163°C. The *polymer* of its methyl ester, methyl methacrylate, is an important *plastic* (Perspex*).

methane Marsh gas, fire-damp. CH_4 . The first *hydrocarbon* of the *alkane series*. An odourless, inflammable *gas*, b.p. -161.5°C., that forms an explosive mixture with air. It is formed from decaying *organic* matter and in coalmines; it occurs in *coal-gas* and *natural gas*.

methanoic acid See *formic acid*.

methanol Methyl alcohol, wood spirit. CH_3OH . A colourless, poisonous *liquid*, b.p. 64.6°C., obtained as wood naphtha by the *destructive distillation* of wood. Used to *denature* *methylated spirit*, as a *solvent*, and in the chemical industry.

methionine An *amino acid* found in *casein*, wool, and other *proteins*, used in the treatment of certain liver diseases. See Appendix, Table 5.

METHOXY

methoxy The univalent radical, $\text{CH}_3\text{O}-$.

methyl The univalent organic radical CH_3- .

methyl alcohol See *methanol*.

methylamine CH_3NH_2 . A gas with an odour of *ammonia*, b.p. -6.3°C .

methyated spirit A liquid fuel consisting, by volume, of 90% *ethanol*, 9.5% *methanol*, 0.5% *pyridine*, together with small amounts of *petroleum* and methyl violet dye.

methyated spirit, industrial A variety of *methyated spirit* free from *pyridine*; it consists of *ethanol* with 5% *methanol*.

methyl chloride See *chloromethane*.

methyl cyanide See *acetonitrile*.

methylcyclohexanol $\text{CH}_3\text{C}_6\text{H}_{10}\text{OH}$. A colourless viscous liquid consisting of a mixture of isomers with b.p. in the range $167-174^\circ\text{C}$.; it is obtained from *cresol* and used as a solvent for rubber and cellulose.

methylene The bivalent radical $\text{CH}_2=$.

methylene blue $\text{C}_{16}\text{H}_{18}\text{N}_3\text{S}\text{Cl}$. A soluble, intense blue dye. Used as a dyestuff, in medicine, and as a stain in biology.

methyl methacrylate See *methacrylic acid*; *polymethyl methacrylate*.

methylol Hydroxymethyl. The univalent radical $\text{HO}\cdot\text{CH}_2-$.

methyl orange $\text{C}_{14}\text{H}_{14}\text{N}_3\text{NaO}_3\text{S}$. An orange indicator, used in acid-base titrations. It is red below a *pH* of 3.1 and yellow above 4.4.

methyl red $\text{C}_{15}\text{H}_{15}\text{N}_3\text{O}_2$. A dark red indicator, used in acid-base titrations. It is red below a *pH* of 4.4 and yellow above 6.0.

methyl salicylate Oil of wintergreen. $\text{OH}\cdot\text{C}_6\text{H}_4\text{COOCH}_3$. A colourless oil, b.p. 223.3°C ., used in flavours, perfumes, and medicine.

metol *p*-methylaminophenol. $\text{CH}_3\text{NH}\cdot\text{C}_6\text{H}_4\text{OH}$. A white crystalline compound, m.p. 87°C . Used as a developer in photography. The same name is often applied to the sulphate of the compound.

metre The SI unit of length. Redefined in 1960 as the length equal to 1 650 763.73 wavelengths in vacuo of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the isotope $^{86}_{36}\text{Kr}$. This definition abrogated the platinum-iridium metre bar as the standard of length. One metre is equal to 39.3701 inches. Symbol m.

metre bridge See *Wheatstone bridge*.

metre-candle See *lux*.

metric system (units) A system of weights and measures originally based upon the *metre*. This was intended to be 1/10 000 000 of a quadrant of the Earth through Paris. See *weight*; *volume*; *length* (metric units of); *c.g.s. system*; *m.k.s. system*; *SI units*.

metric ton Tonne. 1000 kilograms; 2204.61 lb, 0.9842 ton.

metrology The scientific study of weights and measures.

MeV Million electron-volts.

MHD See *magnetohydrodynamics*.

mho Reciprocal ohm. The unit of electrical conductance now known as the *siemens*.

mica A group of *minerals*, the most important of which are muscovite, $\text{H}_2\text{KAl}_3(\text{SiO}_4)_3$, and phlogopite, $\text{H}_2\text{KMg}_3\text{Al}(\text{SiO}_4)_3$. Naturally occurring mica can be split along its cleavages into small thick pieces ('blocks') or thin sheets ('splittings'). Being an excellent insulator and being resistant to high *temperatures*, mica is used as a *dielectric* in *capacitors*, as a support for *electrodes* in *thermionic valves*, and for heating elements in irons, etc. As mica is also transparent it is used for inspection windows of furnaces. Micanite* sheet is manufactured by bonding mica splittings with *shellac* or synthetic resins.

micelle A cluster or group of associated (see *association*) *molecules*, especially in a *colloidal solution*.

Michelson-Morley experiment An attempt to measure the *velocity* of the Earth through the *ether*, by measuring the effect that such a velocity would have upon the velocity of *light*. No such motion of the Earth relative to the ether was detected: a result of the greatest importance for the theory of *relativity*. Named after Albert A. Michelson (1852-1931) and Edward Morley (1838-1923).

micro- 1. Prefix denoting one-millionth, in *metric units*. Symbol μ . 2. Prefix meaning 'very small'; on a small scale. See also *macro-*.

microbalance A *balance* for weighing objects of very small *weight*, i.e. of the order of 10^{-3} to 10^{-6} g.

microbiology The branch of *biology* concerned with the structure and function of *microorganisms*.

microcosmic salt See *ammonium sodium hydrogen orthophosphate*.

microelectronics The design, manufacture, and use of *electronic units* using extremely small *solid-state* components, especially those based on *integrated circuits*.

microfarad μF . One-millionth of a *farad*.

micrometer An instrument for the accurate measurement of small distances or *angles*.

microminiaturization The techniques or the devices used in *microelectronics*.

micron One-millionth of a *metre*. The former name for a micrometre.

microorganism A *unicellular organism* that can only be seen with the aid of a *microscope*.

microphone A device for converting *sound waves* into *electrical energy*, which may then be reconverted into sound after transmission by wire or *radio*. One common type consists of a diaphragm in contact with, or close to, loosely packed carbon granules. The vibration of the diaphragm set up by sound disturbs the packing of the carbon granules and alters the electrical *resistance* of the carbon. Thus an *electric current* flowing through the carbon will vary in a manner that depends upon the *frequency* and intensity of the vibrations produced by the sound on the diaphragm. See also *condenser microphone*; *crystal microphone*.

MICROPHOTOMETER

microphotometer A special form of *densitometer* enabling density variations over a very small area of the image to be measured.

PRINCIPLE OF COMPOUND MICROSCOPE

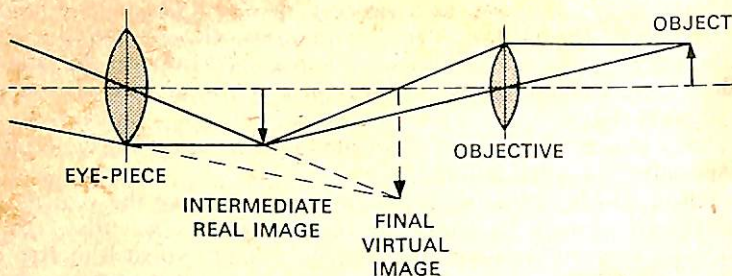


Figure 26.

microscope, compound An instrument consisting essentially of two *converging lenses* or systems of lenses called the *objective* and the *eye-piece* respectively. The objective, which is nearest the viewed object, forms a real inverted magnified *image* of the object just inside the focal distance (see *focal length*) of the eye-piece. This image is viewed through the eye-piece, which then acts as a *simple microscope* producing an inverted further magnified *virtual image*. See Fig. 26. The useful *magnification* obtainable with an optical microscope is limited by the *wavelength* of visible *light* as two points on a microscopic specimen cannot be distinguished from each other if they are not as far apart as half the wavelength of the light used to illuminate them. Thus for magnifications in excess of about 1500, an *ultraviolet microscope* or an *electron microscope* must be used.

microscope, simple Magnifying glass. A *convex lens* used to produce a *virtual image* larger than the viewed object. In Fig. 26, the *eye-piece* is used as a simple microscope.

microtome An apparatus for cutting thin sections of material, for microscopical examination.

microwaves *Electromagnetic radiation* with *wavelengths* ranging from very short *radio waves* almost to the *infrared* region; i.e. wavelengths from 30 cm to 1mm.

microwave spectroscopy The measurement of the absorption or emission of *electromagnetic radiation* in the waveband 0.1 mm to 10 cm by atomic or molecular systems. See *electron spin resonance*.

mil One thousandth of an inch.

milk of lime A *suspension* of *lime* in *water*.

milk sugar See *lactose*.

Milky Way Originally the luminous band of *stars* encircling the heavens. It is now known that these stars are members of the *Galaxy* to which the *Solar system* belongs, and the Galaxy is therefore often referred to as the Milky Way.

milli- Prefix denoting one thousandth, in *metric units*. Symbol m.

milliammeter A sensitive *ammeter* graduated to measure *milliamperes*.

milliampere mA. One thousandth of an *ampere*.

millibar A unit of atmospheric pressure, used in *meteorology*. 1000 dynes per square centimetre or 100 newtons per square metre; approximately equal to 1/32 inch of mercury. See *pressure, units of*.

millicurie One thousandth of a *curie*; the quantity of a *radioactive isotope* that decays at the rate of 3.7×10^7 disintegrations per second.

milligram mg. 1/1000 gram; 0.0154 grain.

millilitre ml. See *litre*.

millimetre mm. 1/1000 metre; 0.0393701 inch. See *length, metric units*.

mineral In the scientific sense, a mineral is a natural *inorganic* substance having a chemical composition in a characteristic range and specific properties. See also *rock*. In popular usage, a substance, usually inorganic, that occurs naturally in the Earth.

mineral oil See *paraffin oil*.

minim British fluid measure; 1/60 of a fluid drachm; 0.0591 cm^3 . See *apothecaries' fluid measure*.

minimum (math.) See *maximum*.

minium See *red lead*.

minority carriers In a *semiconductor*, the type of *carrier* that constitutes less than half the total number of carriers.

minor planets See *asteroids*.

mirror A surface that reflects regularly most of the *light* falling upon it, thus forming *images*. See *reflection*.

mirror image An *image* of an object as viewed in a *mirror*; reversed in such a way that the image bears to the object the same relation as a right hand to a left.

mirrors, spherical *Mirrors* the reflecting surfaces of which form a portion of a *sphere*. The surface of such a mirror may be regarded as being made up of an infinitely large number of very small plane mirrors, each at a *tangent to the curve* of the mirror. Thus a ray of incident *light* would be reflected at any point as if from such a small plane mirror. Spherical mirrors may be *convex*, with the reflecting surface on the outside of the sphere, or *concave*. The centre and radius of the sphere of which the mirror is considered to form a part, are termed the *centre* and *radius of curvature*; the centre of the mirror is the pole, and the line joining the centre of curvature to the pole is the axis. The principal focus (see *focus*) is at a point halfway between the pole and the centre of curvature. Regarding all

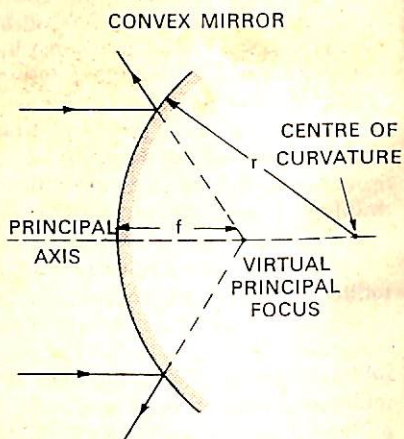
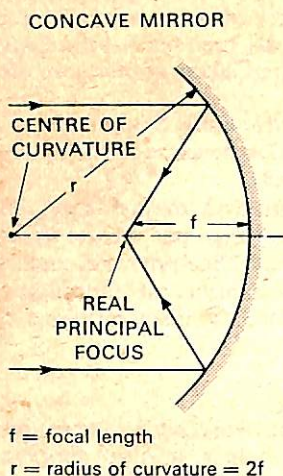


Figure 27.

distances as measured from the mirror and taking all distances in the direction opposite to that of the incident light as positive, the following relationship holds for spherical mirrors:

$$1/v + 1/u = 1/f = 2/r,$$

where u and v are the distances of object and image from the mirror, r the radius of curvature, and f the focal length. See Fig. 27.

Misch metal An alloy of cerium with small amounts of other rare earth metals. Used for 'flints' in automatic lighters.

miscible Capable of being mixed to form a *homogeneous* substance; usually applied to *liquids*, e.g. *water* and *alcohol* are completely miscible.

mispickel Arsenical pyrites. A natural *sulphide* of iron and arsenic, FeAsS .

mist Droplets of *water*, formed by the *condensation* of *water-vapour* on dust particles.

mitochondria Minute rod-shaped or granular bodies, about $\frac{1}{2}$ – $3 \mu\text{m}$ in diameter or length, that occur in the *cytoplasm* of most *cells*. Mitochondria contain many of the *enzymes* of the cell, particularly those required by the *citric acid cycle*.

mitosis The process by which the *nuclei* of *diploid cells* reproduce. It is divided into four stages. 1. Prophase, during which the chromosomes appear as duplicated threads, which become shorter and thicker. 2. Metaphase, during which the nuclear membrane dissolves

and a spindle forms, to the centre of which the chromosomes attach themselves. 3. Anaphase, during which the duplicates of the chromosomes separate and migrate to the ends of the spindle. 4. Telophase, during which two nuclear membranes form, each enclosing one set of chromosomes. The *cytoplasm* also divides in this stage, so that two new diploid cells are formed, each containing a set of chromosomes identical to that of the parent cell.

mixed crystals See *solid solutions*.

mixtures Mechanical mixtures. Mixtures differ from chemical compounds in the following respects: 1. The constituents may be separated by suitable physical or mechanical means. 2. Most mixtures may be made in all proportions; in the case of *solutions*, which may be regarded as molecular mixtures, there are often limits of *solubility*. 3. No *heat effect* (except in the case of solutions) is produced on formation; the formation of chemical compounds is invariably accompanied by the evolution or absorption of *energy* in the form of heat. 4. The properties of a mixture are an aggregate of the properties of the constituents, whereas a compound has individual properties, often quite unlike those of the component *elements*.

m.k.s. system A system of *units* derived from the *metre*, *kilogram*, and *second*. Now superseded for scientific purposes by the *SI units*, which are based on the m.k.s. system.

MMF See *magnetomotive force*.

mmHg A unit of pressure equal to one millimetre of mercury. 1 mmHg = 133.322 *pascals*.

moderator A substance used in *nuclear reactors* to reduce the speed of *fast neutrons* produced by *nuclear fission*. These substances consist of atoms of light *elements* (e.g. *deuterium* in heavy water, *graphite*, *beryllium*) to which the neutrons are able to impart some of their *energy* on collision, without being captured. Neutrons which have been slowed down in this way are much more likely to cause new fissions of ${}_{92}^{235}\text{U}$ than they are to be captured by ${}_{92}^{238}\text{U}$.

modulation The process of varying some characteristic of one wave (usually a *radio frequency carrier wave*) in accordance with some characteristic of another wave. The main types are *amplitude*, *frequency*, and *phase modulation*. See also *velocity modulation*.

module 1. A *unit* used as a standard, especially in architecture. 2. A detachable section of a *spacecraft*. 3. A detachable unit in a *computer system*.

modulus 1. A constant *factor* or multiplier for the conversion of *units* from one system to another. See also *elastic modulus*. 2. See *Argand diagram*.

Moebius strip A rectangular ribbon-shaped strip of paper or material one end of which has been twisted through 180 degrees before attaching it to the other end. This forms a single continuous surface,

MOHO

bounded by a continuous curve. Named after A. F. Moebius (1790-1868).

Moho Mohorovicic discontinuity. The discontinuity between the Earth's crust and its underlying mantle. It lies some 30-40 kilometres below the surface of the land and some 5-9 kilometres below the ocean floor. Earthquake waves suffer an abrupt change of velocity at this discontinuity. A 'mohole' is a hole drilled through the Earth's crust into the discontinuity for research purposes. Named after Andrija Mohorovicic (1857-1936).

Mohs scale of hardness A scale in which each mineral listed is softer than (i.e. is scratched by) all those below it. 1. Talc. 2. Gypsum. 3. Calcite. 4. Fluorite. 5. Apatite. 6. Orthoclase. 7. Quartz. 8. Topaz. 9. Corundum. 10. Diamond.

molality A method of expressing the strength of a solution (see also *concentration*): the number of moles of solute per kilogram of solvent.

molar When the adjective 'molar' is used before the name of an extensive physical property, it implies 'divided by the amount of substance'. This usually, but not always, means 'per mole'. Often denoted by the use of the subscript m, e.g. V_m for molar volume. In some exceptional cases 'molar' is used to mean 'divided by concentration'.

molar electrode potential See *electromotive series*.

molar heat capacity C_m . The heat capacity of a substance, divided by the amount of substance. The amount of heat required to raise the temperature of 1 mole of a substance by 1 kelvin. Expressed in joules per mole per kelvin (*SI units*), or calories per gram-molecule per °C. (*c.g.s. units*).

molarity A word sometimes used for concentration expressed in moles of solute per cubic decimetre of solvent. However, owing to its confusion with *molality* its use for this purpose is deprecated.

molar solution An obsolete expression for a solution with a concentration of 1 mole per dm^3 .

molar volume V_m . Gram-molecular volume. The volume occupied by 1 mole of a substance. All gases have approximately equal molar volumes under the same conditions of temperature and pressure. At 760 mmHg and 0°C., the molar volume of a perfect gas is 22.415 dm^3 per mole.

mole The basic *SI unit* of amount of substance. The amount of substance that contains as many elementary units as there are atoms in 0.012 kg of carbon-12. The elementary units must be specified and may be an atom, molecule, ion, radical, electron, etc., or a specified group of such entities. For example, 1 mole of HCl has a mass of 36.46 g; i.e. 1 mole of a compound has a mass equal to its molecular weight in grams. 1 mole of electrons has a mass of 5.486×10^{-4} g, i.e. $m_e \times N_A$ (see Appendix, Table 2).

The mole replaces such former units as the *gram-atom*, *gram-molecule*, *gram-ion*, and *gram equivalent*. Symbol *mol*.

molecular biology The study of the structure of the *molecules* that are of importance in *biology*.

molecular compounds Chemical *compounds* formed by the chemical combination of two or more complete *molecules*. E.g. the *hydrates* of *salts*.

molecular concentration The *concentration* of a *solution* expressed in terms of *moles* in a given *volume*.

molecular distillation The *evaporation* of *molecules* from a surface, at pressures of about 10^{-2} mmHg, and their subsequent *condensation* under such conditions that their *mean free path* is of the same order as the distance between the heated and cooled surfaces. Used for *isotope separation* and distilling heat-sensitive *organic compounds*.

molecular formula A *formula* of a chemical *compound*, showing the kind and the number of *atoms* present in the *molecule*, but not their arrangement. See *structural formula*.

molecular orbital See *orbital*.

molecular sieves Highly porous *aluminosilicate adsorbents*, containing pores (*lattice vacancies*) of uniform size, that are selective in their action with respect to *molecules* of a particular size and character.

molecular spectrum The *spectrum* emitted by *molecules*. Caused by transitions between different states of molecular rotation, vibration, etc.

molecular volume The *volume* occupied by one *mole* of a substance; equal to its *molecular weight* divided by its *density*.

molecular weight Relative molecular mass. The ratio of the average mass per *molecule* of a specified isotopic composition of a substance to 1/12 of the mass of an *atom* of $^{12}_6\text{C}$. The sum of the *atomic weights* of all the atoms that comprise a *molecule*.

molecular weight determination The following are amongst the available methods: Determination of the *vapour density*; applicable to *gases* and *volatile liquids*. Measurement of the *depression of freezing point*, *elevation of boiling point*, and *osmotic pressure* produced by a definite *concentration* of the substance in *solution*; used for *soluble* substances that do not dissociate or associate in solution. (See *dissociation*; *association*.) Determination of the *chemical equivalent* of the substance, with a knowledge of the *equation* for the reaction.

molecule The smallest portion of a substance capable of existing independently and retaining the properties of the original substance.

mole fraction Mol fraction. The ratio of the number of *moles* of a particular component of a *mixture*, to the total number of moles present in the mixture.

molybdate A salt of *molybdic acid*.

MOLYBDENUM

molybdenum Mo. Element. A.W. 95.94, At. No. 42. A hard white *metal* resembling iron, r.d. 10.2, m.p. 2620°C., that occurs as molybdenite, MoS_2 . It is extracted by roasting the *ore* and reducing the *oxide* so formed in an electric furnace with carbon. Used for special *steels* and *alloys*.

molybdenum trioxide Molybdic anhydride. MoO_3 . A yellow crystalline substance, m.p. 795°C., used in the manufacture of molybdenum *compounds*.

molybdic acid H_2MoO_4 . A yellow crystalline substance that loses a *molecule of water* at 70°C. to form *molybdenum trioxide* (molybdic anhydride).

moment, magnetic See *magnetic moment*.

moment of force A measure of the tendency of a *force* to rotate the body to which it is applied. It is measured by multiplying the magnitude of the force by the perpendicular distance from the line of action of the force to the *axis of rotation*.

moment of inertia The moment of inertia I of a body about any *axis* is the sum of the products of the *mass*, dm , of each element of the body and the *square* of r , its distance from the axis. $I = \sum r^2 dm$.

momentum The product of the *mass* and the *velocity* of a body. For speeds approaching that of *light*, the variation of mass with velocity must be taken into account, and the value of m appropriate to the velocity of the body must be used in the expression for the momentum. See *relativistic mass*.

momentum, conservation of See *conservation of momentum*.

monad An *element* having a *valence* of one.

monatomic molecule A *molecule* of an *element*, consisting of a single *atom* of the element. E.g. the molecules of the *inert gases*.

monazite A *mineral* containing *phosphates* of cerium, thorium, and other *rare earths*, with some occluded helium.

Mond process The extraction of nickel by the action of *carbon monoxide*, CO, on the impure *metal*. This gives *nickel carbonyl*, $\text{Ni}(\text{CO})_4$, a *gas* that decomposes when heated to 200°C. into pure nickel and carbon monoxide, the latter being used again. Named after Ludwig Mond (1839-1909).

Monel metal* An *alloy* of copper (25%-35%), nickel (60%-70%) and small amounts of iron, manganese, silicon, and carbon. Used as an *acid-resisting material* in chemical industry.

mono- Prefix denoting one, single.

monobasic acid An *acid* having one *atom* of *acidic hydrogen* in a *molecule*; an acid giving rise to only one series of *salts*. E.g. *nitric acid*, HNO_3 .

monochromatic light *Light* consisting of vibrations of the same or nearly the same *frequency*; light of one *colour*.

monoclinic Relating to *crystals* that have three unequal axes with one oblique intersection.

monohydrate Containing one *molecule* of water.

monohydric Containing one *hydroxyl group* in a *molecule*.

monolayer Monomolecular layer. A layer or film one molecule thick.

monomere A chemical *compound* consisting of single *molecules*, as opposed to a *polymer*, the molecules of which are built up by the repeated union of monomer molecules. See *polymerization*.

monosaccharides Simple sugars. A group of *carbohydrates* consisting chiefly of *sugars* having a *molecular formula*, $C_6H_{12}O_6$ (*hexoses*) or $C_5H_{10}O_5$ (*pentoses*); unlike the *polysaccharides*, they cannot be hydrolyzed to give simple sugars.

monosodium glutamate See *sodium hydrogen glutamate*.

monotropic Existing in only one *stable* physical form, any other form obtainable being unstable under all conditions.

monovalent Univalent. Having a *valence* of one.

month The 'solar month' is one twelfth of a solar year. The 'calendar month' is any of the twelve divisions of the year according to the Gregorian calendar. The 'lunar month' is the time taken for the *Moon* to complete one *orbit* of the *Earth*. This may be measured in various ways. The 'synodic month' is the period between two successive *phases of the Moon*, equal to 29.5306 days. The 'sidereal month' is the *Moon's* period with respect to successive conjunctions with a *star*, equal to 27.3217 days. The 'anomalistic month' is the *Moon's* period between two successive *perigees*, equal to 27.5546 days. The 'Draconic month' is the *Moon's* period with respect to two successive similar *nodes*, equal to 27.2122 days.

Moon The only *satellite* of the *Earth*. Mean distance from the Earth 384 400 kilometres; synodic *month* 29.5306 days, sidereal month 27.3217 days. Mass 0.0123 that of the Earth; diameter 3476 kilometres. It is devoid of *water* or an *atmosphere*. Man first set foot on the Moon in July 1969.

mordants Substances used in dyeing, especially fabrics of plant origin. The fabric is first impregnated with the mordant, which is generally a *basic metal hydroxide* for *acidic dyes*, or an acidic substance for basic dyes. The dye then reacts chemically with the mordant forming an insoluble *lake*, which is firmly attached to the fabric.

morphine $C_{17}H_{19}O_3N$. A white crystalline *alkaloid* that occurs in *opium*, m.p. 253°C. It is a powerful *narcotic*, used medically in the form of its *sulphate* or *hydrochloride* for relieving pain but it is habit forming and its misuse can be dangerous.

morpholine $O(CH_2CH_2)_2NH$. A colourless *hygroscopic liquid*, b.p. 128°C., used as a *solvent* for *resins* and *waxes*.

morphology The study of the form and structure of *organisms*.

mortar A building material consisting mainly of *lime* and *sand* that hardens on exposure through chemical action between the ingredients and atmospheric *carbon dioxide*.

MOSAIC

mosaic 1. In television cameras (see *camera*, *television*), a device for the electrical storage of the optical image. It usually consists of a sheet of *mica* one side of which is covered with mutually insulated particles of a *photo-emissive* material, each of which is capacitively coupled through the mica to a conducting coating on the reverse side. This conducting coating, called the signal plate, is the output *electrode* from which the electrical signal representing the optical image is obtained. 2. In *nuclear physics*, a *photomicrograph* of a track in an *emulsion*, prepared from a number of photographs of consecutive fields of view and reconstructed as though the track lay in one *plane*.

mosaic gold Crystalline *stannic sulphide*, SnS_2 , consisting of shining, golden-yellow scales.

Mössbauer effect The discovery by R. L. Mössbauer (born 1929) in 1957 that in certain cases appreciable fractions of the *gamma-ray spectrum* emitted by some excited (see *excitation*) *nuclei* may be undisturbed by nuclear recoil or *lattice vibrations* and the consequent *Doppler effects*. The Mössbauer effect has been used to test the predictions of the theory of *relativity* and to investigate the properties of the *solid state* and the nature of *magnetism*.

mother-liquor A *solution* from which substances are crystallized.

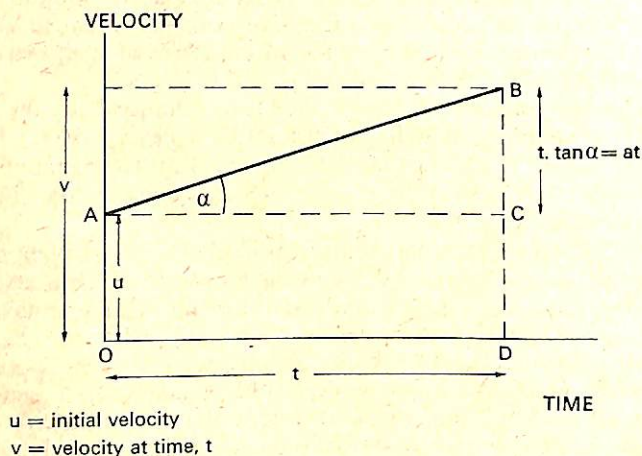


Figure 28.

motion, equations of Kinematic equations that apply to bodies moving with uniform *acceleration*, a ; the equations numbered (1)-(4) below. In the velocity-time graph (Fig. 28):

Gradient of AB = $\tan \alpha = a$

therefore $BC = t \cdot \tan \alpha = at$

and $BD = v = \text{final velocity}$

hence $v = u + at \dots (1)$ where u is the initial velocity.

The area under AB equals the distance covered, s ,

therefore $s = \text{area ACDO} + \text{area ABC}$

i.e. $s = u + \frac{1}{2}at^2 \dots (2)$

Also, using (1); $s = ut + \frac{1}{2}(v - u)t$

or $s = (u + v)t/2 \dots (3)$

Combining (1) & (2), $v^2 = u^2 + 2as \dots (4)$.

motion, laws of See *Newton's laws of motion*.

motor A device for converting other forms of *energy* into mechanical energy. The most common forms are the *internal-combustion engine* and the *electric motor*.

moving-coil ammeter See *ammeter*.

moving-iron ammeter See *ammeter*.

mucoproteins Glycoproteins. *Proteins* that contain a *carbohydrate* group.

multicellular (Of an *organism*). Consisting of more than one *cell*.

multiple proportions, law of See *chemical combination, laws of*.

multiple star A system of *stars* consisting of three or more components held together by *gravitation*.

multiplet 1. A line in a *spectrum* formed by two or more closely spaced lines and resulting from small differences of *energy level* in the atoms or molecules. 2. A group of related elementary particles that differ only in *electric charge*.

multiplication constant (factor) The 'effective' multiplication constant of a *nuclear reactor* is the ratio of the average number of *neutrons* produced by *nuclear fission* per unit time, to the total number of neutrons absorbed or leaking out in the same time. see *subcritical* and *supercritical*.

multiplicity 1. The number of *energy levels* into which an *atom* or *nucleus* splits as a result of coupling between orbital *angular momentum* and *spin* angular momentum. 2. The number of *elementary particles* in a *multiplet*.

Mumetal* An *alloy* of high *magnetic permeability* containing up to 78% nickel in addition to iron, copper, and manganese.

Muntz metal* An *alloy* containing 3 parts of copper and 2 parts of zinc.

muon μ -meson. An *elementary particle* with a *mass* 207 times that of an *electron*; it exists in negatively and positively charged forms. It was originally so called as it was classified as a *meson*. However as these particles have *spin* $\frac{1}{2}$, they are now classified as *leptons*. See Appendix, Table 6.

muriate Obsolete term for *chloride*.

muratic acid Obsolete term for *hydrochloric acid*.

mustard gas Dichlorodiethyl sulphide. $(CH_2CH_2Cl)_2S$. An oily liquid

MUTAGEN

that has been used as a 'war gas'. It is destroyed by *oxidizing agents*, e.g. *bleaching powder*.

mutagen A substance that produces *mutations*.

mutarotation A change in the *optical rotation* of a substance.

mutation A change in the chemical constitution of the *DNA* in the *chromosomes* of an *organism*: the changes are normally restricted to individual *genes*, but occasionally involve serious alteration to whole chromosomes. When a mutation occurs in *gametes* or *gametocytes* an inherited change may be produced in the characteristics of the organisms that develop from them. Mutation is one of the ways in which genetic variation is produced in organisms (see *natural selection*). A *somatic* mutation is one that occurs to a body *cell*, and is consequently passed on to all the cells derived from it by *mitosis*. Natural mutations are relatively rare events, and at this stage of biological evolution, when they occur in the cells of higher animals, almost always produce deleterious characteristics. Artificial mutations can be brought about by *ionizing radiation* (hence the genetic and *carcinogenic* dangers of *nuclear weapons*) and by certain chemical substances.

mutual conductance The ratio of the change of *anode current* to the change in *control grid voltage*, when a small change is made to the control grid voltage in a *thermionic valve*. Used as a measure of the valve's performance. See also *transconductance*.

mutual induction The induction of an *E.M.F.* in a *circuit* due to a changing current in a separate circuit with which it is magnetically linked. The induced *E.M.F.* is proportional to the rate of change of the current in the second circuit, the constant of proportionality being called the coefficient of mutual induction, or the mutual inductance. The derived *SI unit* of mutual inductance is the *henry*.

mycology The branch of *botany* concerned with *fungi*.

mydriatic A substance used to dilate the pupil of the eye.

myoglobin A form of *haemoglobin* that occurs in muscle fibres.

myopia Short sight. A defect of vision in which the subject is unable to see distant objects distinctly. It is corrected by the use of *concave spectacle lenses*.

N

- nadir** (astr.) The lowest point; the point opposite the *zenith* on the *celestial sphere*. See Fig. 2 under *azimuth*.
- nano-** Prefix indicating one thousand millionth. E.g. a nanosecond is 10^{-9} second and a nanometre is 10^{-9} metre. Symbol n.
- naphtha** A mixture of hydrocarbons in various proportions, obtained from *paraffin oil*, *coal-tar*, etc. Wood naphtha is impure *methanol*, CH_3OH , produced by the *destructive distillation* of wood.
- naphthalene** C_{10}H_8 . A white crystalline *cyclic hydrocarbon* with a penetrating odour that occurs in *coal-tar*. M.p. 80.2°C ., b.p. 218°C . Used in the manufacture of organic dyes and in moth-balls.
- naphthol** $\text{C}_{10}\text{H}_7\text{OH}$. Two *isomeric derivatives* of *naphthalene*, both of which darken in colour on exposure to *light*: 1-naphthol (α -naphthol) is a yellow crystalline substance, m.p. 93.3°C ., used in the manufacture of dyes and perfumes; 2-naphthol (β -naphthol) is a white crystalline substance, m.p. 122°C ., used as an *antiseptic* and in the manufacture of dyes, *drugs*, and perfumes.
- naphthoyl** The *univalent radical* $\text{C}_{10}\text{H}_7\text{CO}-$ (from *naphthoic acid*, $\text{C}_{10}\text{H}_7\text{COOH}$).
- naphthyl** The *univalent radical* C_{10}H_7- (from *naphthalene*, C_{10}H_8).
- Napierian logarithm** See *logarithm*. Named after John Napier (1550-1617).
- narceine** $\text{C}_{23}\text{H}_{27}\text{NO}_8 \cdot 3\text{H}_2\text{O}$. A white crystalline *alkaloid* that occurs in *opium*, m.p. 176°C .; used as a muscle relaxant.
- narcotic** Producing sleep, stupor, or insensibility.
- nascent state** Certain *elements*, notably hydrogen, are more active when being set free in a *chemical reaction* than in their ordinary state; such 'nascent' elements are thought to owe their activity to being composed of single *atoms* instead of *molecules*, or alternatively to some of the *chemical energy* liberated on the reaction being associated with the hydrogen instead of being released in the form of *heat*.
- sodium** See *sodium*.
- natron** Natural sodium sesquicarbonate, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$.
- natural** (chem.) Occurring in nature; not artificially prepared.
- natural abundance** The *abundance* of each different *isotope* in an *element* as it is normally found in nature.
- natural frequency** The *frequency* of free oscillation of any system.
- natural gas** A mixture of gaseous *hydrocarbons*, predominantly *methane*, often containing other *gases*, issuing from the Earth in some localities, more particularly near deposits of *mineral oil*. Used

NATURAL LOGARITHM

as a fuel (alone or mixed with *coal gas*) and as a source of *intermediates* for organic synthesis.

natural logarithm See *logarithm*.

natural selection The theory, first proposed by Charles Darwin, that explains the mechanism of biological evolution (see *Darwin's theory of evolution*). According to this theory, the life-forms best adapted to their environment will survive and reproduce in the greatest numbers. As new characteristics arise as small uncontrolled variations (often resulting from genetic *mutations*), those strains of *organisms* with distinctive characteristics best fitting them for their environment will survive.

nautical mile Defined in the U.K. as 6080 ft, but internationally as 1852 metres, 1 U.K. nautical mile therefore equals 1.00064 international nautical miles. 1 international nautical mile equals 1.15078 miles.

near infrared or ultraviolet The shortest *infrared* or the longest *ultraviolet wavelengths*; i.e. those wavelengths of these two types of radiation that are 'nearest' in magnitude to those of visible *light*.

nebula (astr.) A cloudy, luminous patch in the heavens that consists of a *galaxy of stars*, or of materials from which such galaxies are being formed.

negative (math. and phys.) In any convention of signs, regarded as being counted in the minus, or negative direction, as opposed to positive.

negative, photographic See *photography*.

negative feedback See *feedback*.

negative pole The south-seeking pole of a *magnet*. See *magnetic pole*.

negatron Negaton. See *electron*.

nematic crystals *Liquid crystals* in which the molecules are not arranged in layers but all their axes are parallel. See also *cholesteric crystals*; *smetic crystals*.

neodymium Nd. Element. A.W. 144.24. At. No. 60. R.d. 6.9, m.p. 1024°C. See *lanthanides*.

neon Ne. Element. A.W. 20.183. At. No. 10. A colourless odourless invisible *inert gas* that occurs in the *atmosphere* (1 part in 55 000). It is obtained by the *fractional distillation of liquid air*. A discharge of *electricity* through neon at low pressures produces an intense orange-red glow; used for neon signs.

neoplasm New growth of abnormal *tissue* in plants or animals; a tumour, which may be either benign or malignant.

Neoprene* *trans*-Polychloroprene. $(\text{CH}_2.\text{CH}.\text{CCl}.\text{CH}_2)_n$. A synthetic rubber having a high *tensile strength* and better heat and ozone resistance than natural rubber.

neper A unit for expressing the *ratio* of two values (e.g. *currents*, *voltages*, etc.) equal to the natural *logarithm* of the ratio of the quantities. 1 neper = 8.686 *decibels*. Named after John Napier (1550-1617).

nephelometer An instrument for measuring turbidity of *liquids*, or *scattering of light* by particles in *suspensions*.

nephoscope A grid-like instrument for determining the speed of celestial objects (including clouds) by observation of time of transit.

Neptune (astr.) A *planet* with two *satellites*. Its *orbit* lies between those of *Uranus* and *Pluto*. Mean distance from the *Sun* 4496.7 million kilometres; *sidereal period* ('year') 164.8 years; mass 17.46 times that of the *Earth*; diameter 44 800 kilometres. The surface temperature is about -200°C . and the dense atmosphere consists mainly of *methane* and hydrogen.

neptunium Np. *Transuranic element*, At. No. 93. Most stable *isotope*, $^{237}_{93}\text{Np}$, has a *half-life* of 2.2×10^6 years. A *metal* of silvery appearance, r.d. 20.45, m.p. 640°C ., produced as a *by-product* by *nuclear reactors* in the manufacture of plutonium.

Nernst effect If a *temperature gradient* is maintained across an electrical conductor (or *semiconductor*) that is placed in a transverse *magnetic field*, a *potential difference* will be produced across the conductor. Named after Walter Nernst (1864-1941).

Nernst heat theorem The *entropy change* for *chemical reactions* involving crystalline solids, is zero at the *absolute zero* of temperature. See also *thermodynamics*, *laws of*.

nerol $\text{C}_{10}\text{H}_{17}\text{OH}$. A colourless *liquid unsaturated alcohol*, *isomeric* with *geraniol*, b.p. 224°C ., used in perfumes and obtained from *neroli oil*.

neroli oil An *essential oil* obtained from the flowers of orange trees.

nerve cell See *neurone*.

nerve fibre An *axon* or *dendrite*.

nerve gas A war-gas that attacks the nervous system, especially the nerves controlling respiration. Most nerve gases are *derivatives* of *phosphoric acid*.

Nessler's solution A *solution* of potassium mercuric iodide, KHgI_3 , in *potassium hydroxide solution*. Used as a test for *ammonia*, with which it forms a brown coloration or precipitate. Named after Julius Nessler (1827-1905).

neuron(e) Nerve cell. A special type of biological *cell*, being the unit of which the nervous systems of animals are composed. It consists of a *nucleus* surrounded by a *cytoplasm* from which thread-like fibres project. In most neurones impulses are received by numerous short fibres called *dendrites* and carried away from the cell by a single long fibre called an *axon*. Transfer of impulses from neurone to neurone takes place at junctions between axons and dendrites, which are called *synapses*.

neurotoxin A poison that attacks the nervous system.

neutral (chem.) Neither *acid* nor *alkaline*. Containing equal numbers of *hydroxyl* and *hydrogen ions* and having a pH of 7.

NEUTRAL

neutral (phys.) Having neither negative nor positive net *electric charge*.

neutralization (chem.) The addition of *acid* to *alkali*, or vice versa, till neither is in excess and the *solution* is *neutral*.

neutral temperature The temperature of the hot junction of a *thermocouple* at which the *electromotive force* round the circuit is a maximum and the rate of change of E.M.F. with *temperature* is a minimum.

neutretto A *meson* with zero *electric charge*.

neutrino A stable *elementary particle* with no *electric charge* or rest mass, but with *spin* $\frac{1}{2}$. It was originally postulated to preserve the laws of *conservation of mass and energy* and *conservation of momentum*. The existence of the particle has since been established experimentally, and it is known to exist in two forms: one associated with the *beta decay* process and the other with the *muon*. Both forms have antiparticles. See Appendix, Table 6.

neutron An *elementary particle* that is a constituent of all atomic *nuclei* except that of normal hydrogen. The neutron has no *electric charge* and a mass only very slightly greater than that of the *proton* ($1.674\,92 \times 10^{-27}$ kilogram). Outside a nucleus a neutron decays, with a *half-life* of 12 minutes, into a *proton*, an *electron*, and a *neutrino*. Neutrons and protons may be considered as different aspects of the same particles and the name *nucleon* is used to describe both of them.

neutron excess See *isotopic number*.

neutron flux A measure of the number of *neutrons* passing through unit area in unit time.

neutron number *N*. The number of *neutrons* in an atomic *nucleus*; it is equal to the *mass number* minus the *atomic number*.

neutron star A hypothetical state of a *star* at the end of its evolutionary process (see *stellar evolution*) when it has consumed all its *nuclear fuel* and no longer has a source of internal *energy*. The star would then become highly compressed by *gravitational forces* and apart from a thin outer shell would consist only of *neutrons*. Such a star would be expected to have a density some 10^7 times greater than a *white dwarf*. No neutron stars have been identified with certainty, although it is thought that *pulsars* may be this type of star.

neutron temperature The *energies* possessed by *neutrons* in thermal equilibrium with their surroundings may be expressed in terms of a *temperature*, if it is assumed that they behave as a *monatomic gas*. Under these conditions, the neutron temperature on the *Kelvin scale*, *T*, is given by: $E = 3kT/2$, where *E* is the neutron energy and *k* is *Boltzmann's constant*.

new candle See *candela*.

newton The derived *SI unit* of *force*. The force required to give a mass

NEWTON'S LAW OF COOLING

of one *kilogram* an *acceleration* of one *metre* per second per second. Symbol *N*. Named after Sir Isaac Newton (1642-1727).

Newtonian fluid A fluid that obeys Newton's law of viscosity, i.e. the viscosity is independent of the rate of shear or the velocity gradient. The tangential force, F , between two parallel layers of fluid is given by

$$F = \eta A \cdot dv/dx$$

where A is the area of the fluid layers, dx is the distance between them, and dv is their velocity. η is a constant called the coefficient of viscosity. A large number of liquids obey Newton's law. Compare *non-Newtonian fluid*.

Newtonian mechanics A system of *mechanics* developed from Newton's laws of motion. It provides an accurate means of determining the motions of bodies possessing ordinary *velocities*. The motions of particles having very high velocities must be treated by relativistic mechanics, i.e. a system of mechanics based on the theory of *relativity*, as the change of *mass* of a particle with its velocity becomes important under such conditions.

NEWTONIAN TELESCOPE

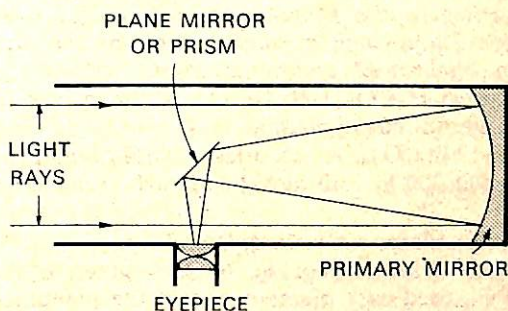


Figure 29.

Newtonian telescope Newtonian Reflector. A form of astronomical reflecting *telescope* consisting of a large *concave* focusing *mirror* on the axis of which is mounted a small plane mirror or reflecting *prism*, enabling the image to be viewed through an *eye-piece*, which is perpendicular to the axis of the main mirror. See Fig. 29.

Newton's law of cooling The rate at which a body loses *heat* to its surroundings is proportional to the *temperature* difference between

NEWTON'S LAWS OF MOTION

the body and its surroundings. It is an *empirical* law, true only for small differences of temperature.

Newton's laws of motion The fundamental laws on which classical *dynamics* is based. 1. Every body continues in its state of rest or uniform motion in a straight line except in so far as it is compelled by external *forces* to change that state. 2. Rate of change of *momentum* is proportional to the applied force, and takes place in the direction in which the force acts. 3. To every action there is an equal and opposite reaction.

Newton's rings Coloured rings that may be observed round the point of contact of a *convex lens* and a *plane* reflecting surface. They are caused by the *interference* effects that occur between *light* waves reflected at the upper and lower surfaces of the air film separating the lens and the flat surface.

niacin See *nicotinic acid*.

Nichrome* Trade name for a nickel-chromium *alloy* used for wire in electrical devices owing to its high *resistance* and its ability to withstand high *temperatures*.

nickel Ni. Element. A.W. 58.71. At. No. 28. A silvery-white magnetic *metal*, resembling iron, that resists corrosion. R.d. 8.90, m.p. 1455°C. It occurs combined with sulphur or arsenic in *pentlandite*, *kupfer-nickel*, *smaltite* and other *ores*. The ore is roasted to form the *oxide*, which is reduced to the metal by hydrogen, and the metal is then purified by the *Mond process*. Used for *nickel-plating*, in coinage, for *alloys* such as *nickel steel*, *nickel silver*, *platinoid*, *constantan*, *Nichrome**, and as a *catalyst*.

nickel acetate $(\text{CH}_3\text{COO})_2\text{Ni} \cdot 4\text{H}_2\text{O}$. A green crystalline *soluble* substance, used in *nickel plating*.

nickel carbonyl $\text{Ni}(\text{CO})_4$. A colourless *volatile liquid*, b.p. 43°C., that decomposes at 200°C. into nickel and *carbon monoxide*. See *Mond process*.

nickel-iron accumulator See *accumulator*.

nickel monoxide Nickelous oxide. NiO . A green *insoluble* powder, m.p. 1990°C., used as a *pigment* and in the manufacture of nickel *compounds*. See also *nickel oxide*.

nickel oxide Nickelic oxide. Ni_2O_3 . A black *insoluble* powder that decomposes into *nickel monoxide* at 600°C., used in *nickel-iron accumulators*.

nickel plating Depositing a thin layer of metallic nickel by an electrolytic process. See *electrolysis*.

nickel silver A group of *alloys* of copper, nickel, and zinc in varying proportions, containing up to 30% nickel. A typical composition is 60% copper, 20% nickel, 20% zinc.

nickel steel *Steel* containing up to 6% nickel.

Nicol prism An optical device, constructed from a crystal of *calcite*,

used for obtaining plane polarized light. Named after William Nicol (1768-1851). See *polarization of light*.

nicotinamide Niacinamide. $C_5H_4NCONH_2$. *Vitamin* of the B complex. A colourless *soluble* substance, m.p. $124^\circ C.$, used in medicine to treat pellagra.

nicotine $C_{10}H_{14}N_2$. A colourless, intensely poisonous oily *liquid*, *alkaloid*, b.p. $247.3^\circ C.$, that occurs in tobacco leaves.

nicotinic acid Pyridine-3-carboxylic acid, niacin. $C_5H_4N.COOH$. *Vitamin* of the B complex. A colourless crystalline *solid*, m.p. $235^\circ C.$, that occurs in meat and yeast; deficiency causes pellagra.

niobium Columbium. Nb. Element. A.W. 92.906. At. No. 41. A rare grey *metal*, r.d. 8.4, m.p. $2500^\circ C$. Small quantities in *stainless steel* preserve the steel's *corrosion* resistance at high *temperatures*.

nit A unit of *luminance* equal to one *candela* per square *metre*.

niton An obsolete name for *radon*.

nitrate A salt or ester of *nitric acid*.

nitration Introduction of the *nitro group*, $-NO_2$, into *organic compounds* by the use of *nitric acid*. It is of importance in the production of *explosives*, many nitro derivatives of organic compounds being chemically *unstable*.

nitre Saltpetre. See *potassium nitrate*.

nitric acid Aqua fortis. HNO_3 . A colourless, corrosive, *acid liquid*, b.p. $86^\circ C.$, that is a powerful *oxidizing agent*. It attacks most *metals* and many other substances with evolution of brown fumes of *nitrogen dioxide*, NO_2 . It is manufactured by the action of concentrated *sulphuric acid*, H_2SO_4 , on *sodium* or *potassium nitrate*, and by the *oxidation* of *ammonia*, NH_3 , by passing a mixture of ammonia and air over heated platinum, which acts as a *catalyst*. Widely used in chemical industry.

nitric oxide NO. A colourless gas that reacts with oxygen on contact to form *nitrogen dioxide*, NO_2 .

nitrides *Binary compounds* of nitrogen.

nitrification 1. The treatment of a substance with *nitric acid*. 2. The process of conversion, by the action of *bacteria*, of nitrogen *compounds* from animal and plant waste and decay, into *nitrates* in the *soil*.

nitrite rubbers A group of synthetic *rubbers* that are copolymers (see *polymerization*) of *butadiene* and *acrylonitrile*. These materials, which can be vulcanized in a similar manner to natural rubber, have a high resistance to *oil*, *fuels*, and *aromatic solvents*. Their properties can be modified by varying the proportions of the constituents; increasing the acrylonitrile content results in greater oil resistance.

nitrite A salt or ester of nitrous acid, HNO_2 .

nitro The *univalent radical* O_2N- .

NITROBENZENE

nitrobenzene $C_6H_5NO_2$. A pale yellow, oily, poisonous liquid, b.p. $211^\circ C.$, with an odour of bitter almonds. It is produced by the action of *nitric acid* on *benzene*; reduction of nitrobenzene yields *aniline*.

nitrocellulose See *cellulose nitrate*. Although the term nitrocellulose is chemically incorrect for this compound, it is extensively used.

nitrochalk A mixture of calcium carbonate, $CaCO_3$, and ammonium nitrate, NH_4NO_3 , used as a fertilizer.

nitrogen N. Element. A.W. 14.0067. At. No. 7. An odourless, invisible, chemically inactive gas, forming approximately $4/5$ of the atmosphere. The chief natural compound is *Chile saltpetre*. Compounds are used as *fertilizers* and in the manufacture of *nitric acid*. The element is vital to living organisms, forming an essential part of *proteins* and *nucleic acids*. See *fixation of atmospheric nitrogen*; *nitrogen cycle*.

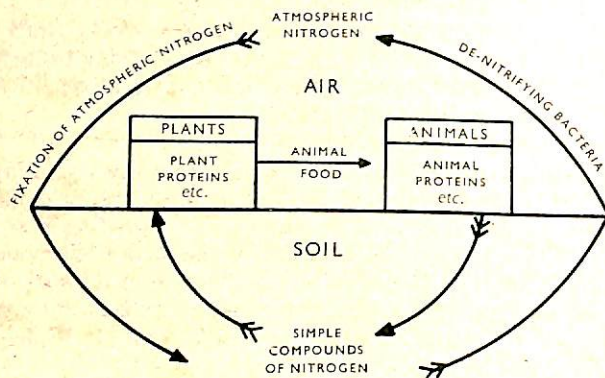


Figure 30.

nitrogen cycle The circulation of nitrogen compounds in nature through the various organisms to which nitrogen is essential. Inorganic nitrogen compounds in the soil are taken in by plants, and are combined by the plants with other elements to form *nucleic acids* and *proteins*, the latter being the form in which nitrogen can be utilized by the higher animals. The result of animal waste and decay is to bring the nitrogen that the animals had absorbed back into the soil in the form of simpler nitrogen compounds. Bacterial action of various kinds converts these into compounds suitable for use by plants again. In addition to this main circulation, a certain amount of atmospheric nitrogen is 'fixed' (i.e. combined) by the action of *bacteria* associated with the roots of leguminous plants,

- and by the action of atmospheric *electricity*; while some combined nitrogen is set free by the action of *denitrifying bacteria*. See Fig. 30.
- nitrogen dioxide** NO_2 . A compound consisting of two forms, the *monomer*, NO_2 , and the *dimer*, N_2O_4 (dinitrogen tetroxide). Below the b.p. (21.15°C .) it consists mainly of N_2O_4 , which is colourless. Its degree of *dissociation* into NO_2 , which is a brown gas, increases with increase of temperature, and the vapour at 150°C . is black. It is formed by *reduction* of *nitric acid* and by the action of heat on some nitrates. Used as an *oxidant* (e.g. for *rocket fuels*) and for *nitration*.
- nitrogen tetroxide** See *nitrogen dioxide*.
- nitroglycerin** Glyceryl trinitrate. $\text{C}_3\text{H}_5(\text{NO}_3)_3$. A pale yellow, heavy, oily *liquid* that explodes with great violence when subjected to sudden shock or detonation. Used as an *explosive*, either alone or in the form of *dynamite*.
- nitrolime** See *calcium cyanamide*.
- nitromethane** CH_3NO_2 . A colourless oily *liquid*, b.p. 100.8°C ., used as a *solvent* and in organic synthesis.
- nitroso** The *univalent radical* $\text{ON}-$ in *organic compounds*. See also *nitrosyl*.
- nitrosyl** The *univalent radical* $\text{ON}-$ in an *inorganic compound*. See also *nitroso*.
- nitrous acid** HNO_2 . A weak *acid*, obtained only in solution; aqueous solutions decompose rapidly to give *nitric acid* and *nitrogen dioxide*. Among its *salts* (*nitrites*), sodium nitrite is used as a source of nitrous acid in *diazotization* (see *diazo compounds*).
- nitrous ether** See *ethyl nitrite*.
- nitrous oxide** Laughing gas. N_2O . A colourless *gas* used as a mild *anaesthetic* in dentistry, etc.
- nobelium** No. *Transuranic element*. At. No. 102. The most stable *isotope*, $^{255}_{102}\text{No}$, has a *half-life* of 3 minutes.
- noble metals** *Metals* such as silver, gold, and platinum, that do not corrode or tarnish in air or water, and are not easily attacked by *acids*. From the chemical point of view, unreactive metals are low in the *electromotive series*.
- nodal points** Two points on the axis of a *lens* system, such that if the incident ray passes through one, travelling in a given direction, the emergent ray passes through the other in a parallel direction.
- nodes** 1. Points of zero displacement in a system of *standing waves*. See also *antinodes*. 2. (astr.) Two points at which the *orbit* of a celestial body intersects the *ecliptic*. 3. (math.) Points on a curve or surface that can have more than one *tangent*.
- noise** (elec.) 1. An effect observed in amplifying circuits due to the amplification, together with the input signal, of spurious *voltages* arising from such causes as the vibration of certain components, the random motion of the *electrons constituting the current* in the

NOMOGRAM

conductors, etc. 2. A term used in *information theory* to indicate a disturbance that does not represent any part of a message from a specified source.

nomogram Nomograph. An alignment chart arranged so that the value of a *variable* can be found, without calculation, from the values of one or two other variables which are known.

nonanoic acid Pelargonic acid, $\text{CH}_3(\text{CH}_2)_7\text{COOH}$. A colourless oily liquid, b.p. $253\text{--}5^\circ\text{C}$., used in the manufacture of lacquers and plastics.

non-conservation of parity See *parity*.

non-electrolytes Substances that do not yield ions in solution and therefore form solutions of low electrical conductivity. See *electrolysis*.

non-ferrous metal Any metal other than iron or steel.

non-metallic elements Chemical elements not possessing the properties of the metals.

non-Newtonian fluid A fluid that does not obey Newton's law of viscosity, i.e. the viscosity is not independent of the rate of shear or the velocity gradient. In *colloids* and other fluids consisting of more than one phase the viscosity usually diminishes as the velocity gradient increases. Compare *Newtonian fluid*.

nor- (chem.) A combining form of *normal*. The prefix is also used to indicate the loss of a methyl group, e.g. noradrenaline, or the loss of a methylene group from a chain.

normal 1. (math.) A line perpendicular to a surface. 2. (chem.) A prefix denoting either a normal solution (abbrev. N-) or an isomer with an unbranched chain (abbrev. n-).

normality (chem.) An obsolescent method of expressing concentrations of solutions; the number of gram-equivalents of reagent per litre of solution. Thus, a solution containing 2 gram-equivalents per litre is a twice-normal or 2N solution.

normalizing A heat treatment applied to steel in order to relieve internal stresses. It involves heating above a critical temperature and cooling in air.

normal solution (chem.) A solution containing 1 gram-equivalent of solute per litre of solution. See *normality*.

normal state of atom See *ground state*.

notation The representation of numbers, quantities, or other entities by symbols; a system of symbols for such a purpose.

nova A star that ejects a small part of its material in the form of a gas cloud. During the process the star becomes 5000 to 10 000 times more luminous than it was before the outburst. 'Dwarf' novae increase their luminosity by a factor of only 10-100. Novae appear to be one of a pair of binary stars. See also *supernovae*.

N-P-N transistor See *transistor*.

N.T.P.; **S.T.P.** Normal (standard) temperature and pressure. A pressure of $1.013\,25 \times 10^5$ pascals and a temperature of $0^\circ\text{C}.$; standard conditions under which volumes of gases are compared.

n-type conductivity The conductivity in a semiconductor caused by a flow of electrons, whereas p-type conductivity is caused by a flow of holes.

nuclear barrier Potential Barrier. The region of high potential energy through which a charged particle must pass on entering or leaving an atomic nucleus.

nuclear charge The positive electric charge on the nucleus of an atom. When expressed in units equal to the charge on the electron, this is numerically equal to the atomic number of the element, to the number of protons in the nucleus, and to the number of electrons surrounding the nucleus in the neutral atom. See *atom, structure of*.

nuclear energy Atomic energy. Energy released during a nuclear reaction as the result of the conversion of mass into energy (see *mass-energy equation*). Nuclear energy is released in nuclear reactors and nuclear weapons.

nuclear fission A nuclear reaction in which a heavy atomic nucleus (e.g. uranium) splits into two approximately equal parts, at the same time emitting neutrons and releasing very large amounts of nuclear energy. Fission can be spontaneous or it may be caused by the impact of a neutron (see *chain reaction*), an energetic charged particle, or a photon (*photofission*). See also *nuclear reactor* and *nuclear weapon*.

nuclear force The attractive force that acts between nucleons when they are extremely close together (closer than 10^{-15} m). The nuclear force replaces the repulsive electromagnetic interaction between protons at such proximities and holds the nucleons together in the atomic nucleus (see *exchange forces*). The precise nature of the nuclear force is not known.

nuclear fuel A substance that undergoes nuclear fission or nuclear fusion in a nuclear reactor, a nuclear weapon, or a star.

nuclear fusion A nuclear reaction between light atomic nuclei as a result of which a heavier nucleus is formed and a large quantity of nuclear energy is released. E.g. the fusion of two deuterium nuclei to form a tritium nucleus and a proton is accompanied by an energy release of 4 MeV ($\text{D} + \text{D} = \text{T} + \text{p} + 4 \text{ MeV}$). For fusion to be possible the reacting nuclei must possess sufficient kinetic energy to overcome the electrostatic field that surrounds them. The temperatures associated with fusion reactions are therefore extremely high. Fusion reactions occur on Earth during the explosion of a hydrogen bomb (see *nuclear weapons*) and during controlled thermonuclear reactions. Fusion reactions are believed to be the source of the energy of the stars (including the Sun).

NUCLEAR ISOMERS

nuclear isomers Atoms of an *element* of the same mass but possessing different rates of *radioactive decay*.

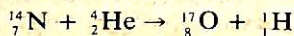
nuclear magnetic resonance NMR. All atomic *nuclei*, except even-even *nuclei*, have *magnetic moments* associated with them, which tend to be aligned by an externally applied *magnetic field*, but because nuclei possess *angular momentum*, they precess (see *precessional motion*) about the direction of the applied field. The *energy* of the interaction between the applied and the nuclear magnetic fields is *quantized* (see *quantum mechanics*), so that only certain orientations of the nucleus relative to the applied field are permitted: a transition from one orientation to another involves the absorption or emission of a *quantum of electromagnetic radiation*, the *frequency* of which can be shown to equal the precessional frequency. With the magnetic field strengths customarily used (up to about 2 *tesla* or 20 *kilogauss*) the energies involved are small, and the radiations fall in the *radio frequency* band, i.e. 1-100 *megahertz*. Transitions from one *energy level* to another can be induced by applying a second magnetic field, at right angles to the first, which rotates in *phase* with the nuclear precession. NMR spectroscopy (also called 'radio frequency spectroscopy') consists of observing the point of *resonance* at which such transitions are induced. Data obtained in this way provide valuable information concerning nuclear properties. As the *orbital electrons* 'shield' the nucleus to a certain extent from the applied magnetic field, at a given frequency nuclei in different electronic (i.e. chemical) environments will resonate at slightly different values of the applied field. This phenomenon, known as the 'chemical shift' enables NMR spectroscopy to be of great value in working out the configuration of complex *molecules*.

nuclear physics The study of the *physics* of the atomic *nucleus* and of sub-atomic particles.

nuclear power Electric or motive power produced from a unit in which the primary *energy source* is a *nuclear reactor*.

nuclear reaction Any reaction that involves a change in the *nucleus* of an *atom*, as distinct from a *chemical reaction*, which only involves the *orbital electrons*. Such reactions occur naturally, on the *Earth* in *radioactive elements*, and in *stars* as *thermonuclear reactions*. They are also produced artificially in *nuclear reactors*, *nuclear weapons*, and controlled thermonuclear reactions. See also *nuclear fission* and *nuclear fusion*.

Nuclear reactions are represented by enclosing within a bracket the symbols for the incoming and outgoing particles or *quanta* (separated by a comma), the initial and final *nuclides* being shown outside the bracket. Thus the reaction:



is represented: $^{14}\text{N}(\alpha, p)^{17}\text{O}$.

nuclear reactor Atomic pile. An assembly in which a *nuclear fission chain reaction* is maintained and controlled for the production of *nuclear energy*, *radioactive isotopes*, or *artificial elements*. The *nuclear fuel* used in a reactor consists of a *fissile material* (e.g. $^{235}_{92}\text{U}$), which undergoes fission, as a consequence of which two *nuclides* of approximately equal mass are produced together with between two and three *neutrons* and a considerable quantity of *energy*. These neutrons cause further fissions so that a chain reaction develops; in order that the reaction should not get out of control, its progress is regulated by neutron absorbers (see *control rods*), only sufficient free neutrons being allowed to exist in the reactor to maintain the reaction at a constant level. The fissile material is usually mixed with a *moderator*, which slows down (see *thermalize*) the *fast neutrons* emitted during fission, so that they are more likely to cause further fissions of the fissile material than they are to be captured by the $^{235}_{92}\text{U}$ isotope. In a 'heterogeneous reactor' the fuel and the moderator are separated in a geometric pattern called a *lattice*. In a 'homogeneous reactor' the fuel and the moderator are mixed so that they present a uniform medium to the neutrons (e.g. the fuel, in the form of a uranium salt, may be dissolved in the moderator).

Besides this classification, reactors may be described in a number of ways. They may be described in terms of neutron energy (see *fast reactor*; *thermal reactor*) or in terms of function, e.g. a 'power reactor' for generating useful *electric power*, a 'production reactor' for manufacturing fissile material (see also *breeder reactor* and *converter reactor*) and a 'propulsion reactor' for supplying motive power to ships or submarines. Reactors are also described in terms of their moderator (e.g. 'graphite-moderated reactor') or their coolant (e.g. *boiling-water reactor*, *gas-cooled reactor*).

The term nuclear reactor may also be applied to a device in which a controlled *thermonuclear reaction* takes place, in this case it is referred to as a 'fusion reactor'.

nuclear transmutations The changing of *atoms* of one *element* into those of another by suitable *nuclear reactions*.

nuclear weapons Weapons in which the explosive power is derived from *nuclear fission* or a combination of nuclear fission and *nuclear fusion*. The fission bomb (atom[ic] bomb or A-bomb) consists essentially of two or more *masses* of a suitable *fissile material* (e.g. $^{235}_{92}\text{U}$ or $^{239}_{94}\text{Pu}$) each of which is less than the *critical mass*. When the bomb is detonated the subcritical masses are brought rapidly together to form a supercritical assembly, so that a single fission at the instant of contact sets off an uncontrolled *chain reaction*. The resulting release of *nuclear energy* produces a devastating *explosion*.

NUCLEASES

the effect of which is comparable to the explosion of tens of *kilotons* of *T.N.T.* The fusion bomb (thermonuclear bomb, hydrogen bomb, or H-bomb) consists of a fission bomb surrounded by a layer of hydrogenous material (e.g. lithium deuteride). At the temperature resulting from the explosion of the fission bomb, fusion of the hydrogen nuclei to form helium nuclei takes place (see *thermonuclear reaction*) with the evolution of even greater quantities of energy. The explosive effect of a fusion bomb (or fission-fusion bomb) is comparable to the explosion of tens of *megatons* of *T.N.T.* See also *fall out*.

nucleases A group of enzymes that break down *nucleic acids*.

nucleation (chem.) The formation of *nuclei*, e.g. preceding crystallization from solutions or in seeding rain clouds.

nucleic acids Large *molecules* consisting of chains of *nucleotides*. They are present in all living matter and are responsible for storing and transferring the *genetic code*. See *deoxyribonucleic acid* and *ribonucleic acid*.

nucleolus A small dense body containing *nucleoprotein*, one or more of which occur in the *nucleus* of biological cells.

nucleon A constituent of the atomic *nucleus*, i.e. a *proton* or a *neutron*.

nucleonics. The practical applications of *nuclear physics*, and the techniques associated with these applications.

nucleon number See *mass number*.

nucleophilic reagents Reagents that react at centres of low *electron density* (e.g. *hydroxyl ions*). Nucleophilic reagents behave as electron donors, either transferring electrons or sharing their electrons with outside *atoms* or *ions*. *Molecules* or ions containing an atom with an unshared electron pair often act as nucleophilic reagents.

nucleoprotein Compounds of *nucleic acids* and *proteins* found in *cell nuclei* principally in the form of *chromosomes*. *Viruses* consist almost entirely of nucleoproteins. Life is based on the self-replicating properties of nucleoproteins.

nucleoside A compound formed from a nitrogenous base (*purine* or *pyrimidine*) and a *pentose sugar*, e.g. adenosine, which consists of *adenine* and D-ribofuranose. The phosphorylated *derivative* of a nucleoside is called a *nucleotide*.

nucleotide A most important type of compound found in all living matter. Nucleotides consist of a nitrogenous base (*purine* or *pyrimidine*), a *pentose sugar* and a phosphate group. They are found free in *cells* as *adenosine triphosphate* and as part of various *coenzymes*; they also occur in the form of *polynucleotide* chains as *nucleic acids*.

nucleus 1. A vital central point, especially a particle of-matter that acts as a centre for the *condensation* of water vapour in mist or as a centre for the formation of crystals. 2. (chem.) A characteristic ring

of *atoms* in a molecule that retains its identity in chemical changes; e.g. the *benzene* nucleus of six carbon atoms in the benzene ring.

nucleus, atomic The positively charged core of an *atom*, consisting of one or more *protons* and, except in the case of hydrogen, one or more *neutrons*. The number of protons in the nucleus is given by the *atomic number* and the number of neutrons by the difference between the *mass number* and the *atomic number* (i.e. the *neutron number*). Nearly the whole of the *mass* of an atom is concentrated in its nucleus, which occupies only a tiny fraction of its *volume*. See *atom*, *structure of*.

nucleus of cell A membrane-bounded body found within the *cytoplasm* of most biological *cells* of both plants and animals. The nucleus contains the *chromosomes*, which become visible under a *microscope* during *mitosis* or *meiosis*. The nucleus is, therefore the repository of the substances that control the characteristics of cells and their progeny.

nuclide Nucleide. The *nucleus* of an *atom* of a specific *isotope*, characterized by its *atomic number*, *mass number*, and its *energy state*. An 'isotope' refers to a type of atom while a 'nuclide' refers to its nucleus.

numerator The number above the line in a *vulgar fraction*. E.g. 3 in $\frac{3}{16}$.

nutaton An oscillation of the *Earth's* poles about the mean position.

nylon Officially defined as 'a generic term applied to any long-chain synthetic *polyamide* that has recurring *amide* groups as an integral part of the main *polymer* chain and is capable of being formed into a filament in which the structural elements are oriented in the direction of the axis'. The familiar commercial form of nylon is a substance formed by the *condensation polymerization* of *adipic acid* with *diaminohexane*. The *solid* polymer is melted and forced through fine jets to make filaments, which are then collected in the form of yarn.

nystatin Fungicidin. A yellow *insoluble antibiotic* obtained from *Streptomyces noursei* and other *Streptomyces* species. Used to treat infections caused by fungi.

objective (phys.) A *lens* or system of lenses nearest the object in a *telescope* or compound *microscope*.

oblate spheroid See *spheroid*.

obtuse angle An angle greater than 90° .

occlusion Certain *solids* have the property of absorbing or occluding some *gases*, either by the formation of a chemical *compound*, by forming a *solid solution*, or by the *condensation* of the gas on the surface of the solid.

occultation The cutting off of the *light* or *radio* emission from one celestial body when another is interposed between it and the observer. E.g. a *star* may become invisible to an *optical* or *radio telescope* when it is hidden behind the *Moon*.

ochre A natural *hydrated* form of *ferric oxide*, Fe_2O_3 , containing various impurities. Used as a red or yellow *pigment*.

octa-, octo- Prefix denoting eight, eightfold.

octacalcium phosphate OCP. $\text{Ca}_2\text{H}(\text{PO}_4)_3 \cdot 2.5\text{H}_2\text{O}$. A crystalline substance of importance in the chemistry of bones, teeth, and precipitated *calcium phosphates*.

octagon An eight-sided *polygon*. The angle between the sides of a regular octagon is 135° .

octahedron A *polyhedron* having eight faces.

octane C_8H_{18} . A *hydrocarbon* of the *paraffin series* that exists in several isomeric forms (see *isomerism*). A colourless *liquid*, b.p. 126°C ., r.d. 0.704.

octane number of a fuel The percentage by volume of *isooctane*, C_8H_{18} (2,2,4-trimethylpentane) in a mixture of *iso-octane* and *normal heptane*, C_7H_{16} that is equal to the *fuel* in knock characteristics (see *knocking*) under specified test conditions.

octanoic acid Caprylic acid. $\text{CH}_3(\text{CH}_2)_6\text{COOH}$. A colourless oily liquid, b.p. 237°C . Used as an *intermediate* in the manufacture of *dyes* and *perfumes*.

octanol Octyl alcohol. $\text{C}_8\text{H}_{17}\text{OH}$. A group of *isomeric alcohols* of which the most important is 1-octanol, a colourless *liquid*, m.p. 16.7°C ., b.p. $194\text{--}5^\circ\text{C}$., used as a *solvent*.

octant The portion of a *circle* cut off by an arc and two radii at 45° ; one-eighth of the area of a circle.

octave The interval between two musical notes, the fundamental components (see *quality of sound*) of which have *frequencies* in the ratio two to one. This use of the word has been extended to include the interval between two frequencies of any type of oscillation that are in the ratio two to one.

octaves, law of An incomplete statement of the *periodic law* made by Newlands independently of Mendeleev.

octet A stable group of eight *electrons* that constitutes the outer electron *shell* of an *atom* of an *inert gas* (except helium whose only electron shell contains two electrons). When the atoms of the *elements* (except hydrogen) combine to form *compounds*, they do so by donating or sharing electrons so that each combining atom has a completed octet in its outer shell. See *valence*, *electronic theory* of.

octyl The *univalent radical*, $C_8H_{17}-$.

odd-even nucleus A *nucleus* that contains an odd number of *protons* and an even number of *neutrons*.

odd-odd nucleus A *nucleus* that contains an odd number of both *protons* and *neutrons*.

oersted The unit of *magnetic field strength* or *magnetic intensity* in c.g.s. *electromagnetic units*, defined as the strength of a magnetic field that would cause a unit *magnetic pole* to experience a force of 1 dyne in a vacuum. Equivalent to $1/4\pi \times 10^3$ amperes per metre. Named after Hans Christian Oersted (1777-1851).

oestrogens Female sex *hormones* of which the most important are the *sterols* oestradiol ($C_{18}H_{24}O_2$), oestrone ($C_{18}H_{22}O_2$), and oestriol ($C_{18}H_{24}O_3$).

ohm The derived *SI unit* of *resistance* defined as the resistance between two points of a *conductor* when a constant difference of potential of 1 volt, applied between these two points, produces in the conductor a *current* of 1 ampere. The former 'international ohm' was defined as the resistance, at $0^\circ C.$, of a column of mercury 106.3 cm in length, of mass 14.4521 g, and of uniform cross-sectional area. 1 'international ohm' = 1.000 49 'absolute' SI ohms. Symbol Ω . Named after Georg Ohm (1787-1854).

ohmmeter An instrument for measuring *resistance* in *ohms*, e.g. a *Wheatstone bridge*.

Ohm's law The ratio of the *potential difference* between the ends of a *conductor* and the *current* flowing in the conductor is constant. This ratio is termed the *resistance* of the conductor. For a potential difference of *V volts* and a current of *I amperes*, the resistance, *R*, in *ohms* is equal to V/I .

oil, synthetic Natural *mineral oils* are composed of various *hydrocarbons*. It is possible to make similar products artificially from coal, etc., by combining carbon or carbon monoxide with hydrogen. See *Bergius process*; *Fischer-Tropsch process*.

oil cake A mass of oilseeds (e.g. linseed, cottonseed) from which the oil has been expelled in a press (expellers) or extracted by a *solvent* (extractions); used as cattle food.

oil-immersion lens See *immersion objective*.

OIL OF VITRIOL

oil of vitriol Concentrated *sulphuric acid*.

oil of wintergreen See *methyl salicylate*.

oils See *fats and oils*.

Olbers' paradox If the Universe contains an infinite number of uniformly distributed stars the night sky should be uniformly bright. In fact it is not: this is explained by the *expansion of the Universe* and the recession of the galaxies. Named after Heinrich Wilhelm Olbers (1758-1840).

oleate A salt or ester of *oleic acid*.

olefiant gas See *ethylene*.

olefins Olefines. See *alkenes*.

oleic acid $C_{17}H_{33}COOH$. An *unsaturated liquid organic acid*, m.p. $15^{\circ}C$., that occurs in the form of *glycerides* in many *fats and oils*. A high proportion of *triolein*, the glyceride of oleic acid, in a fat or oil makes it more liquid.

olein See *triolein*.

oleoyl The *univalent unsaturated radical* $C_{17}H_{33}CO-$ (from *oleic acid*).

oleum Fuming sulphuric acid. *Sulphuric acid* containing *sulphur trioxide* in excess over the formula H_2SO_4 ; e.g. '20% oleum' contains 20% SO_3 and 80% H_2SO_4 . It is extremely corrosive; used in industrial *nitration*.

oleyl alcohol $CH_3(CH_2)_7CH:CH(CH_2)_7CH_2OH$. An *unsaturated liquid alcohol*, b.p. $205^{\circ}C$., used in organic synthesis.

olfactory Pertaining to the sense of smell.

oligomer A *polymer* having comparatively few *monomer* units in the molecule.

olivine $(Mg,Fe)_2SiO_4$. A mineral *silicate* of magnesium and iron. The transparent form is used as a gem.

omega-minus Ω^- . A negatively charged *elementary particle*, classified as a *hyperon* and having a mass 3276 times that of the *electron*.

omegatron An instrument in which *ions* are caused to move in spiral paths by the application of an *electric field* at right angles to a constant *magnetic field*. As the *angular frequency* of rotation of the ions depends upon their *charge to mass* ratio, it is possible by this means to separate ions of different *isotopes*. The instrument may be used for the absolute determination of atomic masses and for isotopic and chemical analysis.

on-line working The use of a device that is connected directly to a *computer* so that it becomes a *peripheral* device. In 'off-line working', the device produces information in readable form for subsequent processing by a computer.

ontogeny (bio.) The history of the development of an individual member of a species, as opposed to 'phylogeny', which is the history of the evolution of the species (or other biological group).

- oocyte** A female *gametocyte* that undergoes *meiosis* to form an *ovum*.
- opacity** The extent to which a medium is *opaque*. Numerically the *reciprocal* of the *transmittance*.
- opaque** Not permitting a *wave motion* (e.g. *light*, *sound*, *X-rays*) to pass. Usually applied to *light*; not *transparent* or *translucent*. See *opacity*.
- open-chain compounds** *Organic compounds* not derived from ring compounds; *aliphatic compounds*.
- open clusters** Clusters of *stars* that have a common motion through *space*. The open clusters are much less densely populated with stars than the *globular clusters*, containing only some hundreds of stars interspersed with *gas* and *dust clouds*.
- open-hearth process** Siemens-Martin process. A process for *steel* manufacture. *Pig-iron* and *steel scrap* or *iron ore* in calculated amounts are heated together by *producer gas* on a *hearth* in a *furnace*.
- operator** A symbol representing a mathematical operation to be carried out on a particular operand.
- operon** A group of *genes* whose function is to control the *synthesis* of the individual *enzymes* that act together as one enzyme system. One of the genes in an operon, known as the 'operator gene', starts and stops the activity of the complete operon.
- opium** The dried, milky juice from unripe fruits of the opium poppy, *Papaver somniferum*. It contains several *alkaloids*, including *morphine*, *narceine*, and *codeine*.
- opposition** (astr.) A *planet* having its *orbit* outside that of the *Earth* is in opposition when the Earth is in a line between the *Sun* and the planet.
- optical activity** Optical rotation. The property possessed by some substances and their *solutions* of rotating the plane of vibration of polarized light (see *polarization of light*). The amount of this rotation is proportional to the distance the light travels in the medium, and to the *concentration* of the solution. The amount of rotation also depends upon the *wavelength* (i.e. the *colour*) of the light used. This last phenomenon is termed 'rotary dispersion'.
- optical axis** Principal axis. The line passing through the *optical centre* and the *centre of curvature* of a spherical *mirror* or *lens*.
- optical centre** A point, situated for all practical purposes at the geometrical centre of a thin *lens*, through which an incident *ray* passes without being deviated.
- optical isomerism** Enantiomorphism. The occurrence of a compound in two different forms, one a mirror image of the other. The two forms have similar properties in all respects except for their *optical activity*, which is different. It occurs in compounds that have an *asymmetric carbon atom*. Optical isomerism is a form of *stereoisomerism*.

OPTICALLY FLAT

optically flat A surface is said to be optically flat if the irregularities do not exceed the *wavelength* of light. This is a requirement for many optical devices.

optical maser See *laser*.

optical pumping See *population inversion*; *laser*; *maser*.

optical rotation See *optical activity*.

optical telescope An astronomical *telescope* used to observe celestial bodies by the *light* that they emit, as compared to a *radio telescope*, which is used to observe their *radio frequency* emissions.

optical temperature The *temperature* of a celestial body as calculated from its *light radiation*.

optic axis The direction in a doubly refracting *crystal* in which *light* is propagated without *double refraction*.

optics The study of *light*.

optics, geometrical The branch of *optics* built up on the laws of *reflection* and *refraction*, and assuming the *rectilinear propagation of light*; it involves no consideration of the physical nature of light. It is mainly concerned with the formation of images by *mirrors* and *lenses*.

orbit 1. The path of one heavenly body around another as a result of their mutual gravitational attraction. Particularly the path of the *planets* around the *Sun*, or the *Moon* (or *artificial satellites*) around the *Earth*. **2.** The path of an *electron* around the *nucleus* of an *atom*. See *orbital electron* and *atom, structure of*.

orbital The space containing all the points in an *atom* or *molecule* at which the *wave function* of an *electron* (two electrons may be present if they have opposite *spins*) has an appreciable magnitude. So called in modern atomic theory by analogy to its counterpart (orbit) in *Bohr's theory*. An atomic orbital (AO), i.e. one associated with a single atomic *nucleus*, has an energy and a shape determined by its *quantum numbers*, and various types (*s*, *p*, *d*, etc.) of AO can be distinguished accordingly. Relative to the nucleus an *s* orbital is spherically symmetrical, whereas a *p* orbital is dumbbell-shaped with a definite orientation in space. In the formation of a *covalent bond* between two atoms, a molecular orbital (MO) containing two electrons and associated with both nuclei is formed. In the formation of a single carbon-carbon bond, as in *ethane*, the MO arises by the overlapping of two AO, and it surrounds the two nuclei and is centred on the line joining them; the bond is called a σ (sigma) bond. In a double carbon-carbon bond, as in *ethylene*, the second bond is formed by the overlapping of two *p* AO and is called a π (pi) bond; the overlapping of the two dumbbells results in the formation of two sausage-like spaces of *electron density* at some distance on each side of the line joining the nuclei. In *benzene*, represented as a ring containing alternating single- and double-bonds, a *p* orbital concerned in the formation of a double bond will

overlap with the *p* orbital of one adjacent carbon atom as much as with that on the other. The result is two *torus*-shaped MO, one on each side of the benzene ring, which thus becomes a symmetrical structure with six identical carbon-carbon bonds. This MO treatment is an alternative to the *resonance* (valence-bond) treatment of molecular structure.

orbital electron Planetary electron. An *electron* contained within an *atom*; it may be thought of as orbiting around the *nucleus*, in a manner analogous to the *orbit* of a *planet* around the *Sun*. See *atom*, *structure of*, and *Bohr theory*.

orbital velocity The *velocity* of a *satellite* or spacecraft that enables it to *orbit* round the *Earth* or other celestial body. A *synchronous orbit* round the Earth requires an orbital velocity of about 3200 metres per second (7200 miles per hour).

orcinol $\text{CH}_3\text{C}_6\text{H}_3(\text{OH})_2\cdot\text{H}_2\text{O}$. A white crystalline substance, m.p. $107-8^\circ\text{C}$., that reddens on exposure to *air*. Used in the analytical detection of *carbohydrates*.

order (math.) The number of times a *function* has been differentiated to give a particular *derivative*: the *degree* of the highest derivative in a *differential equation*.

order of magnitude A magnitude expressed to the nearest power of 10.

ordinary ray When a *ray* of *light* is incident upon a *crystal* that exhibits *double refraction* so that the direction of the ray makes an angle with the *optic axis* of the crystal, the ray splits into two rays. One of these obeys the ordinary laws of *refraction* and is called the ordinary ray. The other is the 'extraordinary ray'.

ordinate In *analytical geometry*, the ordinate of a point is the perpendicular distance of the point from the *x-axis*. See Fig. 5 under *Cartesian coordinates*.

ore A naturally occurring mineral material from which a desired product (usually a *metal*) can be extracted; e.g. *bauxite* is an ore of aluminium.

organic acid An *organic compound* that is able to give up a *proton* to a *base*; i.e. one that contains one or more *carboxyl groups* or in some cases *hydroxyl groups* (e.g. *phenol*).

organic base A *molecule* or *ion* possessing a *lone pair of electrons* that can be used for coordination (see *valence*, *electronic theory of*) with a *proton*. The common *organic compounds* that fulfil this condition owe their basic character to an oxygen or nitrogen *atom*.

organic chemistry The *chemistry* of the *organic compounds*; the chemistry of carbon compounds excluding the *metal carbonates* and the *oxides* and *sulphides* of carbon. Originally, it was the chemistry of substances produced by living *organisms*, as distinct from the *inorganic chemistry* of substances of *mineral* origin.

organic compounds Chemical *compounds* containing carbon combined with hydrogen, and often also with oxygen, nitrogen, and other

ORGANISM

elements. The *molecules* of organic compounds are often very complex, and contain a large number of *atoms*. They are not usually ionized in *solution* (see *dissociation*), and frequently show the phenomenon of *isomerism*.

organism A living animal or plant.

organometallic compound An *organic compound* in which the molecules contain a carbon atom linked directly to a metal atom; e.g. methylsodium, NaCH_3 .

organosilicon compounds Chemical compounds in which *silicon atoms* play the part of carbon atoms in organic compounds; e.g. *silanes* (general formula $\text{Si}_n\text{H}_{2n+2}$) are the organosilicon analogues of *alkanes*.

origin (math.) The point of intersection of two or more axes (see *Cartesian coordinates* and *polar coordinates*).

ormolu An alloy of copper, zinc, and tin in various proportions; generally containing at least 50% copper.

orpiment Natural arsenic trisulphide, As_2S_3 . A yellow mineral.

Orsat apparatus A portable apparatus for determining the amount of carbon dioxide, oxygen, and carbon monoxide in flue or exhaust gases. A measured volume of the gas is successively passed through three tubes, the first of which contains potassium hydroxide to absorb the CO_2 , the second alkaline pyrogallol to absorb O_2 , and the third cuprous chloride in hydrochloric acid to absorb the CO . The diminution of volume after the gas has been passed through each tube indicates the quantity of each constituent gas.

ortho- 1. Prefix denoting right, straight, correct. 2. Denoting adjacency in position in a hexagonal ring of atoms, particularly the benzene ring. Abbreviated to *o-* as a prefix in naming a compound, e.g. *o*-dichlorobenzene (alternatively, 1,2-dichlorobenzene). Compare *meta*; *para*. 3. Prefix indicating an inorganic acid (or a corresponding salt) of a higher degree of hydration; e.g. orthophosphoric acid, H_3PO_4 , as compared with metaphosphoric acid, HPO_3 .

orthochromatic film A photographic film sensitive to green in addition to blue and violet light, thus giving a more accurate representation of colours in monochrome than ordinary film. See *photography*.

orthoclase felspar Natural potassium aluminium silicate, $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$. A constituent of *granite*.

orthogonal 1. (math.) Rectangular, or involving right angles. 2. (of crystals) Having a set of mutually perpendicular axes.

orthohydrogen Hydrogen molecules in which the spins of the two constituent atoms are parallel. Compare *parahydrogen*.

orthophosphoric acid H_3PO_4 . A colourless deliquescent substance, m.p. 42.5°C ., used in fertilizers and as a flavouring agent in drinks.

oscillator 1. A device for producing sonic or ultrasonic pressure waves in a medium. 2. A device with no rotating parts for converting direct

current into *alternating current*; usually consists of *thermionic valves* or *transistors* coupled with a suitable *resonant circuit*.

oscilloscope See *cathode ray oscilloscope*.

osmic acid Osmium tetroxide, OsO_4 . A colourless crystalline *solid*, m.p. 40°C .; *solution* used as a stain for fat globules in microscopy.

osmiridium A natural *alloy* of osmium and iridium, with smaller amounts of platinum, rhodium, and ruthenium. Hard and resistant to *corrosion*; used for tipping pen-nibs.

osmium Os. Element. A.W. 190.2. At. No. 76. A hard white crystalline *metal*. The heaviest substance known; r.d. 22.57, m.p. 3045°C . It occurs together with platinum (see *osmiridium*); used in *alloys* with platinum and iridium.

osmometer An instrument for measuring *osmotic pressures*.

osmosis The flow of *water* (or other *solvent*) through a *semipermeable membrane*; i.e. a membrane that will permit the passage of the solvent but not of dissolved substances. There is a tendency for *solutions* separated by such a membrane to become equal in *molecular concentration*; thus water will flow from a weaker to a stronger solution, the solutions tending to become more nearly equal in concentration.

osmotic pressure The *pressure* that must be applied to a *solution* in order to prevent the flow of *solvent* through a *semipermeable membrane* separating the solution and the pure solvent. When a solvent is allowed to flow through such a membrane into a vessel or cell containing a solution, the solvent will flow into the cell (see *osmosis*) until such a pressure is set up as to balance the pressure of the solvent flowing in. The osmotic pressure of a dilute solution is analogous to gaseous pressure; a substance in solution, if not dissociated (see *dissociation*), exerts the same osmotic pressure as the gaseous pressure it would exert if it were a *gas* at the same *temperature*, and occupying the same *volume*. The osmotic pressure, temperature, and volume of a dilute solution of a *non-electrolyte* are connected by laws exactly similar to the *gas laws*.

Ostwald's dilution law A law relating the dissociation constant, K (see *dissociation*), and the degree of dissociation (or *ionization*), α , of a weak *electrolyte* of *concentration* c moles per litre. This law states that for a binary electrolyte

$$K = c\alpha^2/(1 - \alpha),$$

an equation that applies with a fair degree of accuracy to weak *organic acids* and *bases*. Named after Wilhelm Ostwald (1853-1932).

ouabain $\text{C}_{29}\text{H}_{44}\text{O}_{12}$. A white crystalline *glycoside*, m.p. 200°C ., obtained from wood; used as a heart stimulant.

ounce, avoirdupois $437\frac{1}{2}$ grains; 28.3 grams.

ounce, fluid 8 fluid drachms; 28.41 cm^3 .

OUNCE, TROY

ounce, Troy 480 grains; 31.1 grams.

overtones Notes of lesser intensity and higher pitch (i.e. of higher frequency) than the *fundamental note*, and superimposed upon the latter to give a note of characteristic *quality*.

Ovshinsky device Ovonic device. A device consisting of a special *glass*, which incorporates selenium and tellurium, the *resistance* of which drops rapidly when a suitable *voltage* is applied across it. These devices are used as special purpose switches in *electronic circuits*. The type that stays 'on' after the voltage has been removed is called a 'memory switch'.

ovum A female *gamete* produced by *meiosis* from an *oocyte*.

oxalate A salt or ester of *oxalic acid*.

oxalic acid $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$. A white crystalline poisonous *soluble solid*, m.p. 101°C ., whose *salts* occur in wood sorrel and other plants. Used in dyeing, *bleaching*, *ink* manufacture, metal polishes, and for removing ink stains.

oxidant The substance that supplies the oxygen in an *oxidation* reaction. The term is frequently used with reference to the substance that supplies the oxygen in a *combustion* process, particularly in a *rocket*. The oxidant used in rockets is usually liquid oxygen, *hydrogen peroxide*, or *nitric acid*.

oxidase An *enzyme* that catalyses *oxidation* of the *substrate*.

oxidation The combination of oxygen with a *substance*, or the removal of hydrogen from it. The term is also used more generally to include any reaction in which an *atom* loses *electrons*; e.g. the change of a *ferrous ion*, Fe^{++} , to a *ferric ion*, Fe^{+++} .

oxidation number The number of *electrons* that must be added to a positive *ion* or removed from a negative ion to produce a neutral atom. Pure elements have an oxidation number of 0. In electrovalent compounds the oxidation state is equal to the charge on the ion, e.g. in MgBr_2 the oxidation number of the Mg is +2 and of the Br is -1. In covalent compounds the electrons are notionally assigned to the more electronegative elements. Oxidation numbers are used in naming inorganic compounds, e.g. Fe_2O_3 is sometimes known as iron (III) oxide.

oxidation-reduction reactions See *redox reactions*.

oxide A *binary compound* with oxygen.

oxidizing agent A substance that brings about an *oxidation* reaction.

oxo- Prefix denoting the $\text{O} =$ *radical* in a *compound*.

oxonium The *cation* H_3O^+ .

oxy-acetylene burner A device for obtaining a very high-temperature *flame* (3300°C .) for *welding*, by burning a mixture of oxygen and *acetylene* in a special jet.

oxydiacetic acid See *oxydiethanoic acid*.

oxydiethanoic acid Diglycolic acid, oxydiacetic acid. $\text{O}(\text{CH}_2\text{COOH})_2$.

A white *soluble dibasic organic acid*, m.p. $148^{\circ}\text{C}.$, used in the manufacture of *plastics* and *plasticizers*.

oxygen O. Element. A.W. 15.9994, At. No. 8. An odourless, invisible gas; the most abundant of all the *elements* in the *Earth's crust* including the seas and the *atmosphere*; it forms approximately one fifth of the atmosphere. Oxygen is chemically very active; *combustion* and *respiration* both involve combination with oxygen and *compounds (oxides)* are very widely distributed. The pure element is made by the *fractional distillation of liquid air*. Used for *welding* and metal-cutting.

oxy-haemoglobin An *unstable compound* formed by the action of oxygen on *haemoglobin* in *respiration*.

oxy-hydrogen burner A device similar to the oxy-acetylene burner except that hydrogen instead of *acetylene* is burnt in oxygen; it gives a *flame* temperature of about $2400^{\circ}\text{C}.$

ozokerite Earth-wax. A natural *mixture of solid hydrocarbons*. A brownish or greyish mass, resembling *paraffin wax*.

ozone O_3 . An *allotropic form* of oxygen, containing three *atoms* in the *molecule*. It is a bluish gas, very active chemically, and a powerful *oxidizing agent*. Ozone is formed when oxygen or air is subjected to a silent electric discharge. It occurs in ordinary air in very small amounts only; the health-giving effects sometimes attributed to it in sea-air are probably due to other causes. Ozone in the *atmosphere* is mainly present in the *ozone layer*. Used for purifying *air* and *water*, and in *bleaching*.

ozone layer Ozonosphere. The layer in the *upper atmosphere*, some 15 to 30 kilometres above the *Earth's surface*, in which most of the atmospheric *ozone* is concentrated. It is responsible for absorbing a large proportion of the *Sun's ultraviolet radiation*. Without this absorption the Earth would be subjected to a degree of ultraviolet radiation lethal to plants.

packing fraction The difference between the *mass* of an *isotope* (on the physical scale of *atomic weights*) and its *mass number*, divided by the mass number. E.g. one chlorine isotope has a mass of 32.9860 and a mass number of 33, its packing fraction is therefore:

$$(32.9860 - 33.000)/33 = -0.00042$$

Packing fractions are often multiplied by 10^4 for convenience, and in this example the packing fraction would be given as -4.2.

paint A *liquid* containing a coloured material (*pigment*) in *suspension*. The application of the paint to a surface, and the *evaporation* or hardening of the liquid, covers the surface with the pigment in the form of a skin. The liquid generally consists of *linseed oil*, a 'thinner' of *turpentine* or other *volatile* liquid, and a 'drier' to accelerate drying or hardening of the linseed oil. Paints may also be based on *water* in the form of an *emulsion*, and are then called 'emulsion paints'. Such paints usually consist of an emulsion of *butadiene* and *styrene*, *polyvinyl acetate*, or *acrylic resins* in water.

pair production The creation of a negative *electron* and *positron* as a result of the interaction between a *photon* or a fast particle (usually an electron) and the *field* of an atomic *nucleus* (see also *showers*). 'Internal pair production' occurs as the result of the de-excitation of an excited nucleus. Pair production, which is sometimes extended to mean the creation of any *elementary particle* and its *anti-particle*, is an example of the creation of *matter* from *energy* in accordance with the *mass-energy equation*.

palaeomagnetism The study of the magnetization of iron and iron compounds in rocks. This technique is used to provide a historical survey of the changes in magnitude and direction of the *Earth's magnetic field* since the rocks were formed. It can also be used for dating rocks.

palaeontology The branch of *geology* that is concerned with the study of *fossils* and their relationship to the evolution of the *Earth's crust* and life upon Earth.

palladium Pd. Element. A.W. 106.4. At. No. 46. A silvery-white *metal* that occurs with and resembles platinum. R.d. 11.97, m.p. 1549°C. Used in *alloys* and as a *catalyst*.

palmitic acid $C_{15}H_{31}COOH$. A wax-like *fatty acid*, m.p. 64°C., that occurs in the form of *tripalmitin* in palm oil and many natural *fats*.

It is one of the fatty acids whose *salts* form the basis of soap.

palmitin See *tripalmitin*.

palmitoyl The *univalent radical* $C_{15}H_{31}CO-$ (from *palmitic acid*).

panchromatic film A photographic film sensitive to *light* of all colours including red, thus giving a more accurate representation of colours in monochrome than *orthochromatic film*. See *photography*.

pantothenic acid $C_9H_{17}NO_5$. A white *insoluble solid* member of the *vitamin B* complex, of importance to many *organisms*. It occurs in rice, bran, and plant and animal *tissues*. It is essential for the growth of *cells*.

papain An *enzyme*, found in the fruit and leaves of the pau-pau tree that is capable of digesting *proteins*. Used for softening meat for human consumption.

papaverine $C_{20}H_{21}NO_4$. A white *insoluble alkaloid*, m.p. $147^{\circ}C.$, obtained from *opium*; used in the form of its *hydrochloride* in medicine as an antispasmodic.

paper Paper normally consists of sheets of *cellulose*, mainly obtained from wood pulp from which *lignin* and other non-cellulosic materials have been removed.

paper chromatography A form of *chromatography* in which the mobile phase is liquid and the stationary phase is a strip of porous paper. A drop of the mixture is placed at one edge of the paper and eluted (see *elution*) with the solvent. The components are separated by the rates at which they move across the paper with the solvent. Identification can be by *indicators* or by their *fluorescence* in ultraviolet radiation.

para 1. Prefix denoting beside, beyond; or wrong, irregular. 2. Denoting positions at opposite apexes in a hexagonal ring of atoms, particularly the *benzene ring*. Abbreviated to *p-* as a prefix in naming a compound; e.g. *p*-dichlorobenzene (alternatively, 1,4-dichlorobenzene). Compare *ortho*; *meta*.

parabola A curve traced out by a point that moves so that its distance from a fixed point, the *focus*, is equal to its distance from a fixed straight line, the *directrix*. The equation of a parabola with its vertex at the *origin* and its axis along the *x*-axis is $y^2 = 4ax$, where *a* is the distance from the origin to the focus.

parabolic reflector Paraboloid reflector. A *concave* reflector, the section of which is a *parabola*. Used for producing a parallel beam of *electromagnetic radiation* when a source is placed at its *focus*, or for collecting and focusing an incoming parallel beam of radiation. If the radiation is *light* the reflector is usually called a parabolic mirror, but with *microwave* or *radio frequency* radiation (see *radio telescope*) it may be called a 'dish aerial'.

paraboloid of revolution The surface obtained by rotating a *parabola* about its *axis of symmetry*.

paracasein See *caseinogen*.

parachor A relation showing the influence of *temperature* upon the *surface tension* of a *liquid*; interpreted as the *molecular volume*

PARAFFIN

measured at a standard internal pressure. The value is composed, approximately, of a sum of terms for separate *atoms*, and of constants for various types of linkage between the atoms, thus giving a method for the determination of the constitution and structure of *molecules*.

paraffin (chem.) See *alkanes*.

paraffin oil Kerosine. A mixture of *hydrocarbons* obtained in the *distillation of petroleum*. The boiling range of the kerosines is 150°–300°C. Used for paraffin lamps, oil-burning engines, domestic heaters.

paraffin wax A white translucent *solid* melting to a colourless *liquid* in the range 50°–60°C. It consists of a *mixture* of the higher *hydrocarbons* of the *alkane* series. Used for candles, waxed paper, and polishes.

paraformaldehyde Paraform. $(\text{HCOH})_n$. A solid *polymer* of *formaldehyde*, readily converted into formaldehyde on heating. Used in fumigation.

parahydrogen Hydrogen *molecules* in which the *spins* of the two constituent *atoms* are anti-parallel. Compare *orthohydrogen*.

paraldehyde $(\text{CH}_3\text{CHO})_3$. A liquid *polymer* of acetaldehyde, b.p. 124°C. Used in medicine as a *hypnotic*.

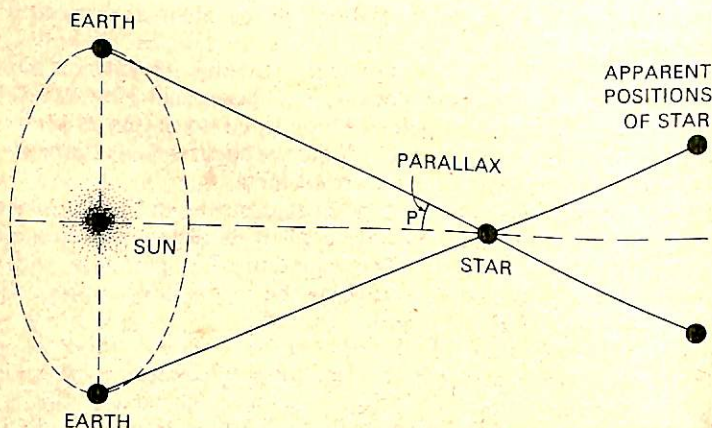


Figure 31.

parallax 1. The difference in direction, or shift in the apparent position, of a body due to a change in position of the observer. 2. (astr.) The apparent displacement of a celestial body due to the point of observation being either on the *Earth's* surface rather than its centre

(diurnal parallax), or on the Earth rather than the centre of the Sun (annual parallax). Annual parallax is expressed as the angle P in Fig. 31.

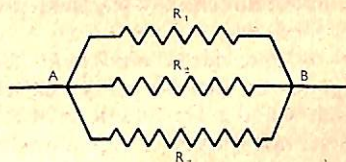


Figure 32.

parallel, conductors in Electrical *conductors* joined in parallel between two points A and B , so that each conductor joins A to B . If R_1 , R_2 , R_3 , etc., are the *resistances* of the separate conductors, the total resistance R between A and B is given by the formula:

$$1/R = 1/R_1 + 1/R_2 + 1/R_3 \dots \text{etc.}$$

See Fig. 32.

parallel beam of light A *beam of light* that neither converges nor diverges. It is a theoretical concept, based on the idea of a beam of light emerging from a source an infinite distance away. *Lasers* are capable of producing nearly parallel beams.

parallelepiped A solid figure having six faces, all *parallelograms*; all opposite pairs of faces being similar and parallel.

parallelogram A plane four-sided *rectilinear* figure having its opposite sides parallel. It may be proved that in all parallelograms the opposite sides and *angles* are equal; the *diagonals* bisect each other; and the diagonals bisect the parallelogram. The *area* of a parallelogram is given by (a) the product of the base and the vertical height, and (b) the product of two adjacent sides and the *sine* of the angle between them.

parallelogram of forces If a particle is under the action of two *forces*, which are represented in direction and magnitude by the two sides of a *parallelogram* drawn from a point, the *resultant* of the two forces is represented by the *diagonal* of the parallelogram drawn from that point.

parallelogram of velocities If a body has two component *velocities*, represented in magnitude and direction by two adjacent sides of a *parallelogram* drawn from a point, the *resultant* velocity of the body is represented by the *diagonal* of the parallelogram drawn from that point.

paramagnetism Substances possessing a *magnetic permeability* slightly greater than unity, i.e. possessing a small positive *magnetic susceptibility*, are said to be paramagnetic. The *atoms* of a paramagnetic substance possess a permanent *magnetic moment* due to

PARAMETER

unbalanced *electron spins* or unbalanced orbital motions of the electrons around the *nucleus* (see *atom, structure of*). Application of a *magnetic field* to such a substance tends to align the magnetic axes of the atoms in the direction of the field, giving the substance a resultant magnetic moment.

parameter 1. In two-dimensional *analytical geometry* it is often convenient to express the variables (x, y) each in terms of a third variable t , such that x and y are functions of t ; $x = f(t)$, $y = g(t)$. The equations are termed parametric equations, and t is a parameter.

2. A variable that can be kept constant while the effect of other variables is investigated.

parametric amplifier An *amplifier of microwaves* that depends on the periodic variation, by an alternating voltage, of the *reactance* of a *thermionic valve* or *semiconductor device*.

parasitic capture The absorption of a *neutron* by a *nuclide* that does not result in a *nuclear fission* or the production of a useful artificial *element*.

Paris green, Schweinfurt green. Cupric acetoarsenite. A double salt of copper arsenite and acetate, $\text{Cu}(\text{CH}_3\text{COO})_2 \cdot 3\text{Cu}(\text{AsO}_2)_2$. Used as a *pigment, insecticide*, and a wood preservative.

parity Space-reflection symmetry. Mirror symmetry. The principle of space-reflection symmetry, or conservation of parity, states that no fundamental distinction can be made between left and right; that the laws of *physics* are the same in a right-handed system of coordinates as they are in a left-handed system. This law holds for all the phenomena described by *classical physics*, but in 1957 it was shown to be violated by certain interactions between *elementary particles*. Interactions between elementary particles are of three types: *strong nuclear interactions*, electromagnetic interactions, and *weak nuclear interactions*. For all strong nuclear interactions and electromagnetic interactions parity is conserved, that is to say, if a left-polarized particle exists (i.e. one that *spins* in an opposite sense to its direction of motion) there will be an approximately corresponding number of right-polarized particles. It has been found, however, that for weak nuclear interactions parity is not conserved. Thus, in a typical weak interaction, such as the *decay* of a *neutron*, the emitted *electron* is always left-polarized. As a result of non-conservation of parity in weak interactions it is now possible to make a fundamental distinction between left and right.

If parity is conserved, it is said to be even (or positive) when the *wave function* of a definite state of a system is left unchanged by reversing the sign of all the coordinates; it is said to be odd (or negative) if the sign of the wave function is thereby changed. If parity is not conserved the wave functions bear no simple relation to each other under these circumstances.

parsec An astronomical unit of distance, corresponding to a *parallax* of one second of arc and equal to 19×10^{12} miles, 3.26 *light-years*, 3.084×10^{16} *metres*.

parthenogenesis The development of an *ovum* into a new individual without *fertilization* by a male *gamete*. It occurs naturally in some plants (e.g. dandelion) and some animals (e.g. aphids) and can be induced artificially in others.

partial derivative The *derivative* of a *function* with respect to only one of its *variables*, all other variables in the function being taken as *constant*.

partial fractions The fractions into which a particular fraction can be separated, so that the sum of partial fractions so obtained equals the original fraction. E.g. the partial fractions of $1/(x^2 - 1)$ are $1/2(x - 1)$ and $-1/2(x + 1)$.

partial pressures See *Dalton's law of partial pressures*.

particle accelerator See *accelerator*.

particle physics The branch of physics concerned with nuclear structure and the properties of *elementary particles*.

partition coefficient The ratio of the concentrations of a single *solute* in two immiscible *solvents*, at equilibrium. For example, if iodine is dissolved in a mixture of water and benzene, some of the iodine molecules will dissolve in the water layer and some in the benzene layer. At equilibrium, the rate at which iodine molecules cross from the water layer to the benzene layer is equal to the rate of the reverse process. The partition coefficient is the equilibrium constant for the process, usually written so that the concentration of the solute in the more soluble phase is the numerator.

parton A basic particle, such as a *quark*, from which other *elementary particles* are formed.

parylene polymers A series of *polymers* derived from di-*p*-xylylene, $(\text{CH}_2\text{C}_6\text{H}_4\text{CH}_2)_2$. Used for *dielectric* coatings in electronic equipment.

pascal The derived *SI unit* of *pressure*, equal to 1 *newton* per square *metre*. Symbol Pa. Named after Blaise Pascal (1623-62).

Pascal's law of fluid pressures *Pressure* applied anywhere to an enclosed body of *fluid* is transmitted equally in all directions. This pressure acts at right angles to every portion of the surface of the container, the *force* per unit *area* being uniform throughout.

Paschen series A series of lines that occurs in the *infrared* region of the *spectrum* of hydrogen. Named after Friedrich Paschen (1865-1947).

Paschen's law The breakdown or 'sparking potential' for a pair of parallel *electrodes* situated in a *gas*, i.e. the *potential* that must be applied between them for sparking to occur, is a *function* only of the product of the *pressure* of the gas and the separation of the electrodes.

PASSIVE

- passive 1.** Denoting an electronic component, such as a *capacitor*, that does not amplify a signal. 2. See *satellites*, *artificial*. Compare *active*.
- passivity** A state of *metals* in which they become resistant to *corrosion*, often after treatment with strong *oxidizing agents*. It has been attributed to the formation of a surface *oxide* film, but other factors may be involved.
- pasteurization** Partial sterilization, especially of milk; it involves heating to a *temperature* sufficiently high to kill *bacteria*, but not spores of bacteria. Named after Louis Pasteur (1822-95).
- pathogenic** Causing disease. A 'pathogen' is an *organism* that causes disease.
- patronite** Vanadium sulphide, VS_4 , a naturally occurring ore from which vanadium is extracted.
- Pauli exclusion principle** Each *electron* moving round the *nucleus* of a *neutral atom* can be characterized by values of four *quantum numbers*. The principle states that no two electrons in a neutral atom can have the same set of four quantum numbers. The principle is of great importance in the theoretical building-up of the *periodic table*. Named after Wolfgang Pauli (1900-1958).
- pearl** A secretion consisting mainly of *calcium carbonate*, $CaCO_3$, produced by various molluscs.
- pearl ash** *Potassium carbonate*, K_2CO_3 , made from wood ashes.
- pearlite** A microconstituent of iron or *steel* consisting of alternate layers of *ferrite* and *cementite*.
- pearl spar** See *dolomite*.
- peat** An early stage in the formation of *coal* from vegetable matter. It is an accumulation of partly decomposed plant material, and is used as *fuel*.
- pectins** A class of complex *polysaccharides* occurring in plants, particularly fruits. *Solutions* have the power of setting to a jelly; this is probably responsible for the 'setting' of jams.
- pelargonic acid** See *nonanoic acid*.
- Peltier effect** When an *electric current* flows across the junction between two different *metals* or *semiconductors*, a quantity of *heat*, proportional to the total *electric charge* crossing the junction, is evolved or absorbed, depending on the direction of the current. This effect is due to the existence of an *electromotive force* at the junction. Named after Jean Peltier (1785-1845). Compare *Seebeck effect*.
- pencil lead** A mixture of *graphite* with *clay* in various proportions, to give different degrees of hardness.
- pencil of light** (phys.) A collection of *rays* proceeding from or towards a point.
- pendulum, simple** A device consisting of a weight or 'bob' swinging on the end of a string or wire. In the case of an ideal pendulum, when

the *angle* described by the pendulum is small, the string has negligible *mass* and the mass of the pendulum is concentrated at one point, the time of one complete swing, T , is given by the formula $2\pi\sqrt{l/g}$, where l is the length of the string, and g the acceleration of free fall.

penetration factor The *probability* that an incident particle, in a nuclear reaction, will pass through the *nuclear barrier*.

penicillin A class of chemically related *antibiotics* produced by the *Penicillium* mould. It is a very powerful agent for preventing the growth of several types of disease *bacteria*.

pennyweight 24 grains, 1/20 Troy ounce. See *Troy weight*.

penta- Prefix denoting five, fivefold.

pentachlorophenol C_6Cl_5OH . A white *insoluble derivative* of *phenol*, m.p. $174^\circ C.$, used as a *fungicide*.

pentaerythritol $C(CH_2OH)_4$. A white *soluble powder*, m.p. $260^\circ C.$, used in the manufacture of *plastics*, *plasticizers*, and *explosives*.

pentagon A five-sided *polygon*: the angle between the sides in a regular pentagon is 108° .

pentane C_5H_{12} . The fifth member of the *alkane* series that exists in three isomeric forms (see *isomerism*). It is contained in light *petroleum*; *n*-pentane has b.p. $36^\circ C.$ and r.d. 0.62. Used as a *solvent*.

pentavalent Quinquevalent. Having a *valence* of five.

pentode A *thermionic valve* containing five *electrodes*: a *cathode*, an *anode* or plate, a *control grid*, and (between the two latter) two other grids called the *screen grid* and the *suppressor grid*.

pentosans *Polysaccharides* that yield *pentoses* on *hydrolysis*.

pentose A *monosaccharide* containing five carbon atoms and having the general formula $C_5H_{10}O_5$. The most important pentose is *ribose*, which is an essential constituent of the *nucleic acids*.

pentyl The *univalent radical* $C_5H_{11}-$; also called *amyl*.

pentyl acetate See *amyl acetate*.

penumbra Half-shadow, formed when an object in the path of rays from a large source of *light* cuts off a portion of the light. See *shadow*.

pepsin A digestive *enzyme* produced in the stomach that converts *proteins* into *peptones*; it acts only in an *acid medium*.

peptidase An *enzyme* that attacks *peptide* linkages and splits off *amino acids*. See also *proteinase*.

peptide A compound of two or more (see *polypeptide*) *amino acids* formed by *condensation* of the $-NH_2$ group of one acid and the *carboxyl group* of another. The *peptide linkage*, $-NH-CO-$, results.

peptones Organic substances produced by the *hydrolysis* of *proteins* by the action of *pepsin* in the stomach. They are *soluble* in *water*, and are absorbed by the body.

PER-

- per-** Prefix denoting, in chemical nomenclature, an excess of the normal amount of an *element* in a *compound*; e.g. *peroxide*.
- perborate** A salt of *perboric acid*, HBO_3 .
- perboric acid** HBO_3 . A hypothetical *acid* known only in the form of its salts, the *perborates*; e.g. *sodium perborate*.
- perchlorate** A salt of *perchloric acid*, HClO_4 .
- perchloric acid** HClO_4 . A colourless *hygroscopic liquid*, b.p. 390°C ., that forms salts called *perchlorates*.
- percussion cap** A device used in fire-arms. It consists of a small copper cylinder containing *mercuric fulminate* or other violent *explosive* that will explode on being struck, thus initiating the explosion of the main charge.
- perfect gas** Ideal gas. A theoretical concept of a gas that would obey the *gas laws* exactly. Such a gas would consist of perfectly elastic *molecules*, the *volume* occupied by the actual molecules, and the *forces* of attraction between them, being zero or negligible.
- peri-** Prefix denoting around, about.
- periclase** Natural *magnesium oxide*, MgO .
- pericynthion** The time of, or the point of, the nearest approach of a *satellite* in *lunar orbit* to the *Moon's* surface. Opposite of *apocynthion*.
- perigee** The *Moon*, the *Sun*, or an artificial *Earth satellite*, are said to be in perigee when they are at their least distance from the Earth. Opposite of *apogee*.
- perihelion** The time of, or the point of, the nearest approach of a *planet* to the *Sun*. Opposite of *aphelion*. See Fig. 1, under *anomaly*.
- perimeter** The distance all round a *plane figure*; e.g. the perimeter of a *circle* is its circumference.
- period** (phys.) If any quantity is a *function* of the time, and this function repeats itself exactly after constant time intervals T , the quantity is said to be periodic, and T is called the period of the function.
- periodate** A salt of a *periodic acid*.
- periodic acids** A series of *unstable acids* formed by the addition of *water* to the hypothetical iodine heptoxide, I_2O_7 , e.g. HIO_4 . They are known in the form of their salts, the *periodates*.
- periodic law** The statement that 'the properties of the *elements* are in periodic dependence upon their *atomic weights*', published by Mendeleev in 1869. The law is brought out clearly when the elements are arranged in the *periodic table*.
- periodic table** An arrangement of the chemical *elements* in order of their *atomic numbers* in such a way as to demonstrate the *periodic law*. In such an arrangement elements having similar properties occur at regular intervals and fall into groups of related elements. From the position of an element in the periodic table its properties may be predicted with a fair measure of success; Mendeleev was

able to forecast the existence and properties of then undiscovered elements by means of his original table. The periodic law has since been shown to reflect the grouping of *electrons* in the outer *shells* of the *atoms* of the elements. Elements with the same numbers of electrons in their outer shells have similar chemical properties, as these electrons determine the valences (see *valence*, *electronic theory of*) of the atoms. See Appendix, Table 8.

peripherals Peripheral devices. Devices connected to the *C.P.U.* or the high-speed *store* of a *computer*. Forming part of the *hardware*, they include *backing storage*, input and output devices, *on-line equipment*, *visual display units*, etc.

periphery The external surface or boundary of a body; the circumference or *perimeter* of any closed figure.

periscope A device for viewing objects that are above the eye-level of the observer, or are placed so that direct vision is obstructed. Essentially it consists of a long tube, at each end of which is a right-angled *prism*, so situated that, by *total internal reflection* at the longest faces, *light* is turned through an angle of 90° by each prism. Thus light from a viewed object enters the observer's eye in a direction parallel to, but below, the original direction of the object.

Permalloy* A class of iron-nickel *alloys* with high *magnetic permeability*. Used in parts of electrical machinery that are subject to alternating *magnetic fields* as they cause only low losses of *energy* due to *hysteresis*.

permanent gas A *gas* that cannot be liquefied by *pressure* alone; a gas above its *critical temperature*.

permanent hardness of water Hardness that is not destroyed by *boiling* the *water*. See *hard water*.

permanent magnetism Magnetic properties of substances (especially *steel*) possessed without the influence of an external *magnetic field*.

permanganate A *salt* of *permanganic acid*, HMnO_4 , especially *potassium permanganate*.

permanganic acid HMnO_4 . A hypothetical *acid* known only in *solution* or in the form of its *salts*, the *permanganates*.

permeability A body is said to be permeable to a substance if it allows the passage of the substance through itself.

permeability, magnetic See *magnetic permeability*.

permittivity ϵ . 1. The absolute permittivity of a medium is the ratio of the *electric displacement* to the strength of the *electric field* at the same point. The absolute permittivity of free space, ϵ_0 , is a fundamental constant, called the *electric constant*. It has the value $8.854\,185 \times 10^{-12} \text{ F m}^{-1}$. 2. The relative permittivity, ϵ_r , also called the *dielectric constant*, is the ratio of the capacitance of a capacitor with a specified medium (*dielectric*) between the plates, to the capacitance of the same capacitor with free space between the plates, i.e. $\epsilon_r = \epsilon/\epsilon_0$.

PERMUTATION

The value of the relative permittivity of some common dielectrics is given in the table.

Material	Relative Permittivity	Dielectric Strength V/mm
Air	1	—
Paraffin Wax	2.0–2.5	6.2×10^4
Rubber	2.8–3.0	1.2×10^5
Shellac	3.0–3.7	$3-9 \times 10^4$
Bakelite	4.5–7.5	$2-9 \times 10^4$
Porcelain	6.0–8.0	10^4-10^5
Mica	6.0–8.0	$2-6 \times 10^4$

permutation (math.) An arrangement of a specified number of different objects. E.g. the six possible permutations of the digits 123 are 123, 132, 213, 231, 312, 321. The number of possible permutations of n objects if all are taken each time, denoted by ${}^n P_n$, is *factorial* n . The number of permutations of n different objects taken r at a time, ${}^n P_r$, is $n!/(n-r)!$.

peroxide 1. An oxide that yields *hydrogen peroxide* with an acid. **2.** An oxide that contains more oxygen than the normal oxide of an element.

perpendicular At right angles; a straight line making an angle of 90° with another line or *plane*.

perpetual motion The concept of a machine that, once set in motion, will go on for ever without receiving *energy*. It is impossible to make a machine that will go on for ever and be able to do *work*, i.e. create energy without receiving energy from outside. To do so would contravene the first two laws of *thermodynamics*.

persistence of vision The sensation of *light*, as interpreted by the brain, persists for a brief interval after the actual light stimulus is removed; successive images, if they follow one another sufficiently rapidly, produce a continuous impression. Use is made of this in the cine-projector and in *television*.

personal equation The time interval or lag peculiar to a person between the perception and recording of any event. In many physical observations an error is introduced by the time-lag between the actual occurrence of the observed event, its perception by the observer, and its recording.

Perspex* See *polymethyl methacrylate*.

persulphate A salt of a *persulphuric acid*.

persulphuric acids 1. Permonosulphuric acid, Caro's acid. H_2SO_5 . A white crystalline substance that decomposes at $45^\circ C.$, used as an oxidizing agent. **2.** Perdisulphuric acid. $H_2S_2O_8$. A white crystalline

substance that decomposes at 65°C., used in the manufacture of *hydrogen peroxide*.

perturbations Deviations in the motions of the *planets* from their true elliptical *orbits*, as a result of their gravitational attractions for each other.

pesticides Substances that kill pests; they include *insecticides*.

peta- Prefix denoting one thousand million million; 10^{15} . Symbol P, e.g. Pm = 10^{15} metres.

Petri dish A shallow flat-bottomed circular glass dish, which may have a fitting cover; used in laboratories for a variety of purposes, especially for cultivating *microorganisms*. Named after J. R. Petri (died 1921).

petrification The change of an *organic* structure, such as a tree, into a stony or mineral structure. It is generally caused by dissolved *hydrated silica*, SiO_2 , penetrating into the pores and gradually losing its water.

petrochemicals Chemical substances derived from *petroleum* (or *natural gas*).

petrol Gasoline. A complex *mixture* consisting mainly of *hydrocarbons*, such as *hexane*, *heptane*, and *octane*; other *fuels* and special ingredients are often added.

petrolatum Petroleum jelly, Vaseline*. A purified mixture of *hydrocarbons* consisting of a semi-solid whitish or yellowish mass.

petroleum Mineral oil. A natural *mixture* of *hydrocarbons* and other *organic compounds*. The composition of petroleum varies according to their source; e.g. American petroleum contains a high proportion of *alkanes* while Russian petroleum is rich in *cyclic hydrocarbons*. *Fractional distillation* yields *petrol*, *paraffin oil*, lubricating oil, *petrolatum*, and *paraffin wax*.

petroleum ether A *mixture* of the lower *hydrocarbons* of the *alkane series* consisting mainly of *pentane* and *hexane*. B.p. 30°-70°C.

petrology The study of the origin, structure, and composition of rocks.

pewter An *alloy* of approximately 4 parts of tin to 1 of lead, with small amounts of antimony.

phage See *bacteriophage*.

phagocyte A *blood cell* (particularly a *leucocyte*) that can engulf a foreign particle or *bacterium*.

pharmacology The study of the action of chemical substances upon animals and man.

pharmacophore The portion of a *molecule* of a substance that is regarded as determining the special physiological action of the substance.

pharmacy The preparation and dispensing of *drugs* and medicines.

phase (chem.) A separate part of a *heterogeneous* body or system. E.g. a *mixture* of ice and water is a two-phase system, while a *solution* of salt in water is a system of one phase.

PHASE

- phase** (phys.) 1. Points in the path of a wave *motion* are said to be points of equal phase if the displacements at those points at any instant are exactly similar; i.e. of the same magnitude and varying in the same manner. 2. One of the circuits in a system or apparatus in which there are two or more alternating *voltages* displaced in phase (meaning as I) relative to one another. In a 'two-phase' system the displacement is one quarter of a *period*, in a 'three-phase' system it is one third of a period.
- phase angle** 1. (phys.) The *angle* between the *vectors* representing two harmonically varying quantities (e.g. *current* and *voltage*) that have the same *frequency*. 2. (astr.) The *angle*, seen from the *Moon* or a *planet*, between the *Earth* and the *Sun*.
- phase contrast microscope** A *microscope* that uses the difference in *phase* of the *light* transmitted or reflected by an object to form an *image* by relative differences in *intensity*.
- phase diagram** A diagram showing the relations between various *phases* in a chemical system, and the effects of composition and conditions (temperature, pressure) on them.
- phase modulation** *Modulation* of the *phase angle* of a *sinusoidal carrier wave*. The *phase* of the modulated wave differs from that of the carrier by an amount proportional to the instantaneous value of the modulating wave.
- phase rule** $F + P = C + 2$. For a *heterogeneous* system in equilibrium, the sum of the number of *phases* plus the number of *degrees of freedom* is equal to the number of *components*, plus two. E.g. with *ice*, *water*, and *water vapour* in equilibrium, the number of phases is 3, the number of components 1, and hence the number of degrees of freedom is 0; the system is said to be invariant, since no single variable can be changed without causing the disappearance of one phase from the system.
- phases of the Moon** The various shapes of the illuminated surface of the *Moon* as seen from the *Earth* (new Moon, first quarter, full Moon, third quarter); due to variations in the relative positions of *Earth*, *Sun*, and *Moon*.
- phenacetin** p-ethoxyacetanilide. $\text{CH}_3\text{CONHC}_6\text{H}_4\text{OC}_2\text{H}_5$. A white crystalline substance, m.p. 134.7°C ., used to relieve pain and as an *antipyretic*.
- phenazine** $\text{C}_6\text{H}_4\text{N}_2\text{C}_6\text{H}_4$. A yellow crystalline substance, m.p. 171°C ., used in the manufacture of *dyes*.
- phenetole** $\text{C}_6\text{H}_5\text{OC}_2\text{H}_5$. Phenyl ethyl ether. A *volatile aromatic liquid*, b.p. 172°C .
- phenobarbitone** Luminal. Phenylethylbarbituric acid. $\text{C}_6\text{H}_5\cdot\text{C}_2\text{H}_5\cdot\text{C}:(\text{NHCO})_2:\text{CO}$. A white crystalline powder, m.p. 174°C .; used as a sedative and *hypnotic* drug usually in the form of the *soluble sodium salt*.

- phenol** Carbohic acid. C_6H_5OH . A white crystalline *solid*, m.p. $41^\circ C.$, with a characteristic 'carbohic' smell. It is *soluble* in water, corrosive, and poisonous. Used as a *disinfectant* and in the manufacture of *plastics* and *dyes*.
- phenol-formaldehyde resin** Phenolic resin. A very widely used type of synthetic *resin* produced by the *condensation* of *phenols* with *formaldehyde*: it forms the basis of *thermosetting* moulding materials, and is also used in *paints*, *varnishes*, and *adhesives*.
- phenolphthalein** $C_{20}H_{14}O_4$. A colourless crystalline *solid*, m.p. $261^\circ C.$ A solution in *alcohol* turns a deep purple-red in the presence of *alkalis*, and is used as an *indicator*. It is also used in *dye* manufacture and as a laxative.
- phenols** A class of *aromatic organic compounds* containing one or more *hydroxyl groups* attached directly to the *benzene ring*. They correspond to the *alcohols* in the *aliphatic* series, forming *esters* and *ethers*, but they also have weak *acidic* properties and form *salts*. See *phenol*.
- phenothiazine** Thiodiphenylamine. $C_6H_4NH.S.C_6H_4$. A green *insoluble* substance, m.p. $185.5^\circ C.$, used as an *insecticide* and in the manufacture of drugs.
- phenotype** 1. The characteristics possessed by an individual *organism* as a result of the interaction of its inherited characteristics (see *genotype*) with its environment. 2. A group of organisms having the same phenotype (meaning 1).
- phenyl** The *univalent radical* C_6H_5- .
- phenylalanine** A crystalline *soluble amino acid*, m.p. $283^\circ C.$, obtained from eggs and milk. It is essential to the diet of mammals. See Appendix, Table 5.
- phenylene** The bivalent *radical* $-C_6H_4-$, which exists in the *ortho*, *meta*, and *para* isomeric forms.
- pheromones** Chemical substances secreted by an *organism* that elicit a behavioural response from other organisms of the same species, especially substances that act as sex attractants.
- phlogiston theory** A theory of *combustion* that was generally accepted during the eighteenth century until it was refuted by Lavoisier. All combustible substances were supposed to be composed of phlogiston, which escaped on burning, and a calx or ash, which remained. Replacement of phlogiston into the calx would restore the original substance.
- phon** A unit of loudness, used in measuring the intensity of *sounds*. The loudness, in phons, of any sound is equal to the intensity in *decibels* of a sound of *frequency* 1000 *hertz* that seems as loud to the ear as the given sound.
- phonon** The *quantum* of thermal energy in the lattice vibrations of a crystal. If f is the vibrational *frequency* the magnitude of the phonon is hf , where h is *Planck's constant*.

PHOSGENE

phosgene Carbonyl chloride. COCl_2 . A colourless, poisonous gas with a penetrating smell resembling musty hay. Used as an *intermediate* in organic synthesis.

phosphate A salt of *phosphoric acid*, H_3PO_4 . Phosphates are used as *fertilizers* to rectify a deficiency of phosphorus in the soil.

phosphine PH_3 . A colourless, inflammable poisonous gas with an unpleasant smell.

phosphinic acid See *hypophosphorous acid*.

phosphite A salt of *phosphorous acid*, H_3PO_3 .

phospholipids Phosphatides. Compound *lipids* that contain *phosphoric acid* groups and nitrogenous bases. They are found in brain tissue and in egg yolk.

phosphor A substance that is capable of *luminescence*, i.e. storing energy (particularly from *ionizing radiation*) and later releasing it in the form of *light*. If the energy is released after only a short delay (between 10^{-10} and 10^{-4} second) the substance is called a 'scintillator'.

phosphor bronze An alloy of copper (80%-95%), tin (5%-15%), and phosphorus (0.25%-2.5%) that is hard, tough, and elastic.

phosphorescence A form of *luminescence* in which a substance emits *light* of one wavelength after having absorbed *electromagnetic radiation* of a shorter wavelength. Unlike *fluorescence*, phosphorescence may continue for a considerable time after *excitation*.

phosphoric acid See *orthophosphoric acid*, metaphosphoric acid, and pyrophosphoric acid.

phosphorous acid H_3PO_3 . A colourless *deliquescent* crystalline substance, m.p. 73.6°C ., from which *phosphites* are obtained.

phosphorus P. Element. A.W. 30.9738. At. No. 15. It occurs in several *allotropic forms*, white phosphorus (r.d. 1.82) and red phosphorus (r.d. 2.20) being the commonest. The former is a waxy white, very inflammable and poisonous *solid*, m.p. 44°C . Red phosphorus is a non-poisonous, dark red powder, that is not very inflammable. The *element* occurs only in the combined state, mainly as *calcium phosphate*, $\text{Ca}_3(\text{PO}_4)_2$. It is extracted by heating with *coke* and *silica* (sand) in an electric furnace, and distilling off the phosphorus. Phosphorus is essential to life; calcium phosphate is the main constituent of animal bones. *Compounds* are used as *fertilizers* and *detergents*.

phosphorus pentoxide P_2O_5 . A *deliquescent* colourless crystalline *solid*, m.p. 563°C ., used as a drying agent.

phosphorus trichloride PCl_3 . A colourless fuming *liquid*, b.p. 75.5°C ., used as a chlorinating agent.

phosphoryl The trivalent radical $=\text{PO}$.

phot Unit of *illumination*; an illumination of one *lumen* per square centimetre.

photocathode A *cathode* that emits *electrons* when it is illuminated, i.e. as a result of the *photoelectric effect*.

photocell See *photoelectric cell*.

photochemical reactions *Chemical reactions* initiated, assisted, or accelerated by exposure to *light*. E.g. hydrogen and chlorine combine explosively on exposure to sunlight but only slowly in the dark.

photochemistry The branch of physical chemistry concerned with the effects of radiation on chemical reactions.

photochromism Phototropism. The property of certain *dyes*, or other *compounds*, that undergo a reversible change in the *colours* they absorb when exposed to *light* of different *wavelengths*. Thus some photochromic materials will darken in bright light, but will revert to their original colour when the source of light is removed.

photoconductive effect A *photoelectric effect* in which the electrical *conductivity* of certain substances, notably selenium, increases with the intensity of the *light* to which the substance is exposed.

photodisintegration 1. A *nuclear reaction* caused by a *photon* in which the *nucleus* emits charged fragments or *neutrons*. 2. See *photodissociation*.

photodissociation Photodisintegration. The *dissociation* of a chemical *compound* as the result of the absorption of *radiant energy*.

photoelectric cell Photocell. A device used for the detection and measurement of *light*. The cell may depend for its action upon (1) the normal *photoelectric effect*; the cell is then called a *photoemissive cell*; (2) the *photovoltaic effect* (*rectifier* or *barrier layer cell*); or (3) the *photoconductive effect* (*conductivity cell*). Photoemissive cells consist of two *electrodes*, a plane *cathode* coated with a suitable *photosensitive material*, and an *anode* that is maintained at a positive *potential* with respect to the cathode and that attracts the *photoelectrons* liberated by the latter. These electrodes are arranged in an envelope that is either evacuated, or, for greater sensitivity, contains a *gas* at low *pressure*. The *electric current* passing through the cell is a measure of the *light* intensity incident on the cathode. For rectifier or barrier cells, the *potential difference* developed across the boundary gives rise to a current when the faces of the cell are connected externally. This current can be measured directly by suitable means, such as a *galvanometer*. Rectifier cells require no external source of *E.M.F.* and are very convenient for photographic *exposure meters*, etc. The conductivity cell is simply an arrangement for measuring the *resistance* of a layer of material, usually selenium, which shows the photoconductive effect.

photoelectric effect In general, any effect arising as a result of a transfer of *energy* from *light* incident on a substance to *electrons* in the substance. The term is normally restricted to one type of the effect, namely the emission of electrons by substances when irradiated with

PHOTOELECTRON

light of a *frequency* greater than a certain minimum *threshold frequency*. Electrons liberated in this way are called photoelectrons, and constitute a photoelectric current when the system is included in a suitable circuit.

photoelectron An *electron* emitted from a surface as a result of illumination, i.e. by the *photoelectric effect* or by *photoionization*.

photoemissive Capable of emitting *electrons* when subjected to *electromagnetic radiation*. The *wavelength* of the radiation that will provoke such emission depends upon the nature of the substance: *light* provokes some *metals* into photoemission, other materials require *ultraviolet radiation* or *X-rays*.

photofission Nuclear *fission* caused by *photons* (of *gamma-rays*).

photography By means of a system of *lenses* in the *camera* an image of the object to be photographed is thrown for a definite length of time on to a plate or *film* made of *glass*, *celluloid*, or other *transparent material* and covered with an *emulsion* containing *silver bromide*, *AgBr*, or *silver chloride*, *AgCl*. The effect of this exposure of the film to make the silver compound easily reduced (see *reduction*) to metallic silver by the chemical action of *developing*; developers produce a black deposit of fine particles of metallic silver on those portions of the film that had been exposed to *light*, thus giving a negative image. *Fixing* consists of the chemical action of *sodium thiosulphate*, $\text{Na}_2\text{S}_2\text{O}_3$, ('*hypo*'), and other *reagents* on the unchanged silver salts to give a *soluble compound*, which is then washed out with *water*, leaving a negative free of light-sensitive silver salts. By placing the finished negative over a piece of sensitive paper similar to film, and exposing to light, the silver salts in the paper are affected in a similar way to those in the original film; those portions of the negative that were darkest let through least light, and thus give the whitest portions on the developed paper. The negative image is thus again reversed, and a correct image or photograph is obtained on the paper, which is then fixed and washed as before.

photoionization The ionization of an *atom* or *molecule* as the result of exposure to radiation. If the *frequency* of the radiation is *f*, each *photon* will have an energy hf , where *h* is *Planck's constant*. Photons with energies in excess of the *ionization potential* of the atoms struck will cause ionization to occur.

photoluminescence *Luminescence* caused by *electromagnetic radiation*. The emitted light always has a lower frequency than the radiation absorbed. Whiteners used in *detergents* consist of photoluminescent substances that absorb *ultraviolet radiation* and emit blue light.

photolysis The *decomposition* of a chemical compound as the result of *irradiation* by *light* or *ultraviolet radiation*. 'Flash photolysis' is a method of identifying the free *radicals* formed when the *vapour* of a compound at low pressure is exposed to an intense, but very brief,

flash of radiation. A second flash, following shortly after the first, is used to photograph the *absorption spectrum* of the *gases*, which records the free radicals present. Subsequent flashes at regular intervals may be used to calculate the lifetimes of the radicals so formed.

photomeson A *meson* produced by the interaction between a *photon* and an atomic *nucleus*.

photometer An instrument for comparing the *luminous intensity* of sources of *light*. In *astronomy* *photoelectric* photometers are used to measure the intensity of *light* from distant *stars*.

photomicrograph A photograph obtained with the aid of a *microscope*.

photomultiplier Electron multiplier. A *photoelectric cell* of high sensitivity used for detecting very small quantities of *light* radiation. It consists of a system of *electrodes* suitably arranged in an evacuated envelope. Light falling on the first electrode ejects *electrons* from this surface (see *photoelectric effect*). These electrons are accelerated to the second electrode, where they each produce further electrons by the process of *secondary emission*. This process continues until the secondary emission from the final electrode is sufficient to produce a useful *electric current*, permitting measurement or the operation of a *relay*.

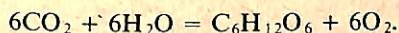
photon A *quantum* of *electromagnetic radiation* that has zero *rest mass*, and *energy* equal to the product of the *frequency* of the radiation and *Planck's constant*. Photons are generated when a particle possessing an *electric charge* changes its *momentum*, in collisions between *nuclei* or *electrons*, and in the *decay* of certain nuclei and particles. In some contexts it is convenient to regard a photon as an *elementary particle*.

photopic vision Vision in which the cones in the eye are the principal receptors. It occurs under normal lighting conditions and colours can be distinguished. Compare *scotopic vision*.

photosensitive Substances are said to be photosensitive if they produce a *photoconductive*, *photoelectric*, or *photovoltaic effect* when subjected to suitable *electromagnetic radiation*.

photosphere The visible, intensely luminous portion of the *Sun*, which has an estimated *temperature* of 6000 K.

photosynthesis The process by which green plants manufacture their *carbohydrates* from atmospheric *carbon dioxide* and *water* in the presence of sunlight. The reaction, which is highly complex in detail, may be summarized by the equation:



When *light* falls upon green plants the greater part of the *energy* is absorbed by small particles called *chloroplasts*, which contain a variety of pigments, amongst them *compounds* called *chlorophylls*. The *chlorophylls* transform the *energy* of the *light* into *chemical*

PHOTOVOLTAIC EFFECT

energy by a process that is not fully understood, but it is known to involve the *photolysis* of water and the activation of *adenosine triphosphate* (ATP). The energy-rich ATP subsequently energizes the fixation of the CO_2 , after a series of reactions, so that *sugar molecules* are formed. As animals are unable to fix atmospheric CO_2 in this way, they depend for their carbon on the plants (or other animals) that they consume. Photosynthesis is therefore essential to all the higher life forms, either directly or indirectly.

photovoltaic effect A *photoelectric effect* in which *light* falling on a specially prepared boundary between certain pairs of substances (e.g. copper and *cuprous oxide*) produces a *potential difference* across the boundary.

phthalic acids $\text{C}_6\text{H}_4(\text{COOH})_2$. Three *isomeric* acids. 1. Phthalic acid, the *ortho* form, 1,2-benzenedicarboxylic acid, is a white crystalline solid, m.p. 207°C ., that decomposes into *phthalic anhydride* and water and is used in organic synthesis. 2. The *meta* form, 1,3-benzenedicarboxylic acid. See *isophthalic acid*. 3. The *para* form, 1,4-benzenedicarboxylic acid. See *terephthalic acid*.

phthalic anhydride $\text{C}_6\text{H}_4(\text{CO})_2\text{O}$. The *anhydride* of *o-phthalic acid*, formed from the latter on heating, m.p. 130.8°C . It is made industrially by the *oxidation* of *naphthalene* in the presence of a catalyst and is an important *intermediate* in the production of *dyes*, *resins*, and other organic products.

phthalocyanines Organic colouring matters, usually of outstanding resistance to the action of light and other agencies. The parent compound, phthalocyanine, is a *condensation* product of nitrogen-containing derivatives of *phthalic acid*; its molecule contains a ring of 16 atoms (carbon and nitrogen) similar to that in natural *porphyrins*. Four nitrogen atoms in this ring are positioned so as to form a small square in the centre of the molecule, and a metal atom, e.g. copper, can occupy a central position in the square becoming bonded to all four nitrogen atoms to form an extremely stable *chelate complex*. For example, copper phthalocyanine is a very stable brilliant-blue pigment.

pH value See *hydrogen ion concentration*.

phylogeny See *ontogeny*.

physical change Any change in a body or substance that does not involve an alteration in its chemical composition.

physical chemistry The study of the *physical changes* associated with *chemical reactions* and the dependence of physical properties on chemical composition.

physical states of matter The physical state in which *matter* exists, at a particular *temperature* and *pressure*, depends upon the *kinetic energy* of, and interaction between, its component *atoms*, *molecules*, or *ions*. In *gases* the distance between the fast moving atoms or molecules is such that the interaction between them is very small

(see *Van der Waals' forces*); they are therefore free to move about the space that contains them almost independently of each other (see *kinetic theory of gases*). In the *solid state* the atoms, molecules, or ions have insufficient kinetic energy to overcome the strong *forces* between them, they therefore vibrate about the fixed positions of a *crystal lattice*. *Liquids* represent an intermediate state between gases and solids. Raising the temperature of a solid increases the kinetic energy of its components so that they are able to overcome the forces between them, the solid then becomes a liquid and eventually a gas. Increasing the pressure of a gas increases the number of collisions between the components and thus facilitates their interactions; for this reason increased pressure causes, or assists in, the *liquefaction of gases*. A hot ionized *plasma* has sometimes been referred to as the fourth state of matter.

physics The study of the properties of *matter* and *energy*.

physiological saline An *isotonic solution* of salts in *distilled water* used for preserving *cells*. Such solutions contain no food for the cells and their survival in them is therefore restricted.

physiology The study of the functioning of the various organs of living beings.

physisorption See *adsorption*.

physostigmine Eserine. $C_{15}H_{21}O_2N_3$. A colourless *alkaloid*, m.p. $105-6^\circ\text{C}$., used in the treatment of glaucoma.

phytamins See *auxins*.

phyto- Prefix denoting 'plant'; e.g. a phytocide is a substance that kills plants.

pi π . Symbol for the ratio of the circumference of any *circle* to its diameter, 3.141 59... (Approximately 22/7.)

pi bond π bond. See *orbital*.

pico- Prefix denoting one million millionth. E.g. a picofarad is 10^{-12} farad. Symbol p.

picoline Methylpyridine. $\text{CH}_3\text{C}_5\text{H}_4\text{N}$. A *heterocyclic base* that exists in three *isomeric* forms. All three isomers are found in *coal-tar* and *bone oil*; they are used as *solvents* and as *intermediates* in *organic synthesis*.

picrate A *salt* or *ester* of *picric acid*.

picric acid 2,4,6-trinitrophenol. $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{OH}$. A bright yellow crystalline *solid*, m.p. 122°C . Formerly used as an explosive (see *lyddite*), as a *dye*, and (in *solution*) for treating burns.

piezoelectric effect A property of certain *asymmetric crystals*. When such crystals are subjected to a *pressure*, positive and negative *electric charges* are produced on opposing faces; the signs of these charges are reversed if the pressure is replaced by a tension. The inverse piezoelectric effect occurs if such crystals are subjected to an *electric potential*, an alteration in size of the crystal taking place.

PIG-IRON

- pig-iron** An impure form of iron obtained from iron ores by the *blast furnace* process. See *cast iron*.
- pigment colour** Body colour. The *colour* of most natural objects is due to the differential absorption by the substance of the different *wavelengths* (i.e. colours) present in the incident white *light*. The incident light penetrates a small distance into the substance, undergoes this absorption and is then diffusely reflected out again. The colour the body appears is determined by the wavelengths absorbed the least. Thus, a substance that absorbs chiefly the red and yellow will appear blue. See also *surface colour*.
- pigments** 1. Materials used generally in the form of insoluble powders for imparting various colours to *paints*, *plastics*, etc. 2. Natural colouring substances in plant or animal tissues.
- pile, voltaic** See *voltaic pile*.
- pilocarpine** $C_{11}H_{16}N_2O_2$. A white crystalline *alkaloid*, m.p. $34^\circ C.$, used in medicine.
- pinchbeck** An *alloy* of copper and zinc used as an imitation gold.
- pinch effect** 1. The constriction of a *liquid conductor of electricity* (e.g. mercury or molten *metal*) that occurs when a substantial *current* is passed through it. 2. The constriction of a *plasma* due to the *magnetic field* of a high current within the plasma. See *thermonuclear reactions*.
- pinene** $C_{10}H_{16}$. A *liquid terpene*, b.p. $156.2^\circ C.$, that is the principal constituent of *turpentine* and is found in other *essential oils*. Used in the manufacture of *camphor*.
- pinking** See *knocking*.
- pink salt** Ammonium chlorostannate, $(NH_4)_2SnCl_6$. Used as a *mordant* in dyeing.
- pint** Unit of capacity equal to one eighth of a *gallon*.
- pion** A *pi-meson*. A type of meson. See Appendix, Table 6.
- piperazine** Hexahydropyrazine. $C_4H_8(NH)_2$. A colourless *deliquescent heterocyclic base*, m.p. $108^\circ-110^\circ C.$, used mainly as a *vermifuge*.
- piperidine** $C_5H_{10}NH$. A colourless *liquid*, b.p. $106^\circ C.$, used as a *solvent*.
- piperine** $C_{17}H_{19}NO_3$. A white crystalline *alkaloid*, m.p. $129.5^\circ C.$, the active constituent of pepper.
- pipette** A glass tube with the aid of which a definite *volume* of *liquid* may be transferred.
- Pirani gauge** A type of pressure gauge used to measure low pressures. An electrically heated wire is placed in the gas, the rate of loss of heat from the wire depending on the gas pressure. It may either be used with a fixed potential difference across the wire, the resistance of which is then a measure of the pressure, or at a fixed resistance so that the p.d. is a measure of the pressure.
- pitch** Hard dark substances that melt to viscous tarry *liquids*; they may

be the residue from the *destructive distillation* of wood, coal-tar, asphalt, or various *bitumens*, etc.

pitchblende A natural *ore* consisting mainly of uranium oxide, U_3O_8 . It occurs in Saxony, Bohemia, East Africa, and Colorado. Pitchblende contains small amounts of radium, of which it is the principal source.

pitch of a note A measure of the *frequency* of vibration of the source producing the note; a high frequency produces a note of high pitch. See *sound*.

pitch of a screw The distance between adjoining crests of the thread, measured parallel to the *axis* of the screw.

Pitot tube An instrument for measuring the *velocity* of a *fluid*; it consists of a tube with two openings, one facing the moving fluid and the other facing away from it. The difference in *pressure* created in the tube between the two openings, as measured by a *manometer*, allows the velocity of the fluid to be determined. Named after Henri Pitot (1695-1771).

pK A measure of the strength of an *acid*, defined as $\log 1/K$, where K is the *equilibrium constant* of the *dissociation* of the acid. The higher the value of pK, the weaker the acid.

Planck's constant h The universal constant relating the *frequency* of a *radiation*, ν , with its *quantum of energy*, E ; i.e. $E = h\nu$. Planck's constant has the dimensions of *action* (energy \times time) and its value is $6.626\,196 \times 10^{-34}$ *joule second*. The symbol \hbar is often used for $h/2\pi$. Named after Max Planck (1858-1947).

Planck's law of radiation The *energy* of *electromagnetic radiation* (including *light*) is composed of discrete *quanta*, the magnitude of which is given by the *product* of *Planck's constant* and the *frequency* of the radiation.

plane (math.) A flat surface; mathematically defined as a surface containing all the straight lines passing through a fixed point and also intersecting a straight line in space.

plane-polarized light See *polarization of light*.

planetarium 1. A complex system of optical projectors for representing the movements of the *planets* and *stars* on a domed ceiling. 2. The building that houses such a system.

planetoids See *asteroids*.

planets Heavenly bodies revolving in definite *orbits* about the *Sun*. In order of increasing distance from the Sun they are *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, *Saturn*, *Uranus*, *Neptune*, and *Pluto*. See Appendix, Table 4.

planimeter A mechanical integrating instrument for measuring *plane* areas, consisting of a movable tracing arm the movements of which are recorded on a dial.

plano- Prefix used in conjunction with the words *concave* and *convex* to describe the shape of a *lens*. See Fig. 24, under *lens*.

PLANT HORMONES

plant hormones Compounds that affect or regulate the growth of plants.

See *auxins*; *gibberellins*; *cytokinins*.

plasma (bio.) See *blood plasma*.

plasma (phys.) 1. The region in a *discharge in gases* in which the numbers of positive and negative *ions* are approximately equal. 2. The very hot ionized gas in which controlled *thermonuclear reaction* experiments are carried out. In such a plasma, which has been described as the fourth state of matter, the *ionization* is virtually complete. Again the numbers of positive ions and electrons are approximately equal and the plasma is therefore virtually electrically *neutral* and highly conducting. See also *containment*.

plasmolysis An effect of *osmosis* on *cells* of living *organisms*. A cell placed in a *solution* of a greater *molecular concentration* than (i.e. is *hypertonic* to) the contents of the cell becomes plasmolyzed; the *water* in the cell flows out through the cell wall and the cell contents contract.

plaster of Paris Powdered *calcium sulphate*, $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$, obtained by heating *gypsum* to 120°C .– 130°C . On mixing with water, it sets and hardens.

plasticizer 1. A non-volatile *liquid* added to *paints* and *varnishes* to prevent brittleness of the dried film. 2. A liquid or *solid* substance added to synthetic or natural *resins* to modify their flow properties.

plastics Materials that are *stable* in normal use, but at some stage of their manufacture are plastic and can be shaped or moulded by *heat*, *pressure*, or both. Most plastics are polymers (see *polymerization*), and are classified into *thermoplastic* and *thermosetting* materials.

platelet See *blood platelet*.

platinic Containing *tetravalent* platinum.

platinized asbestos *Asbestos* in the fibres of which a black deposit of finely-divided platinum has been formed. Used as a *catalyst*.

platinoid An *alloy* of 60% copper, 24% zinc, 14% nickel, and 2% tungsten.

platinous Containing *bivalent* platinum.

platinum Pt. Element. A.W. 195.09. At. No. 78. A hard silvery-white ductile and malleable metal, r.d. 21.45, m.p. 1773.5°C ., that is very resistant to both heat and acids. Its coefficient of *expansion* is very nearly equal to that of glass, which makes it useful in certain types of scientific equipment. It occurs as the metal, alloyed with osmium, iridium, and similar metals. Used for electrical contacts, scientific apparatus, as a *catalyst* (see *platinized asbestos*), and in jewellery.

platinum chloride solution See *chloroplatinic acid*.

platinum metals A group of six *transition elements* with similar metallic properties. They are: ruthenium, rhodium, palladium, osmium, iridium, and platinum.

pleochroic Denoting certain *crystals* that have different colours, depending on the direction from which they are observed.

plumbago Black-lead, *graphite*. A natural *allotropic form* of carbon.

Pluto A *planet* with its *orbit* outside that of *Neptune*. Discovered in 1930, its mean distance from the *Sun*, is 5907 million kilometres. *Sidereal period* ('year') 248.4 years. *Mass* approximately one tenth that of the *Earth*, diameter approximately 5900 kilometres. Pluto's surface temperature is probably below -200°C .

plutonium Pu. At. No. 94. *Transuranic element*. Different *isotopes* of plutonium can be produced by suitable *nuclear reactions*. The isotope $^{239}_{94}\text{Pu}$ is produced in *nuclear reactors* and is of considerable importance since it undergoes *nuclear fission* when bombarded by *slow neutrons*. This isotope, which has a *half-life* of 24 400 years, is also used in *nuclear weapons*, one kilogram having an energy equivalent of about 10^{14} joules. It is a dense silvery metal, r.d. 19.84, m.p. 639.5°C .

pneumatic Operated by, or filled with, compressed air.

pnigogens A collective term sometimes used (but not recommended) for the elements *nitrogen*, *phosphorus*, *arsenic*, *antimony*, and *bismuth*.

P-N-P transistor See *transistor*.

point-contact transistor See *transistor*.

point defect See *defect*.

point source of light A theoretical concept of a source of *light* in which all the light is emitted from a single point.

poise A unit of *viscosity* in *c.g.s. units* defined as the tangential force per unit area (*dynes* per sq cm) required to maintain unit difference in *velocity* (cm per second) between two parallel *planes* separated by one centimetre of *fluid*. 1 centipoise = 10^{-3} newton second per square metre (the *SI unit* of viscosity).

Poiseuille's equation The volume V of a *liquid* flowing through a cylindrical tube per second is given by the equation $V = \pi pr^4/8l\eta$, where p is the *pressure* difference between two points on the axis of the tube at a distance l apart, η is the coefficient of *viscosity* and r is the radius of the tube. The result assumes uniform *streamline* flow, and also that the liquid in contact with the walls of the tube is at rest. Named after Jean Louis Poiseuille (1799-1869).

poison, nuclear Reactor poison. A substance that absorbs *neutrons* in a *nuclear reactor*. Poisons may be deliberately added to reduce the reactivity, or they may be *fission products*, such as xenon, which have to be periodically removed.

Poisson's ratio The ratio of the *lateral strain* to the *longitudinal strain* in a stretched wire. Given by the ratio of d/D to l/L , where D = original diameter, L = original length, d = decrease in diameter, and l = increase in length. Named after Simeon Poisson (1781-1840).

polar bond An electrovalent bond. See *valence*, *electronic theory of*.

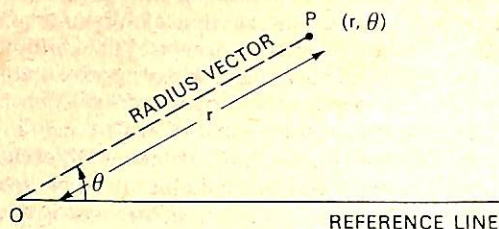


Figure 33.

polar coordinates The position of any point P lying in a *plane* can be completely determined by (1) its distance, r , from any selected point O in the plane, termed the *origin*, and (2) the *angle* θ that the line joining P and O (called the *radius vector*) makes with any *coplanar* reference line passing through O . The angle is taken as positive when measured anti-clockwise from the reference line. The polar coordinates at the point P are r and θ , denoted by (r, θ) . See Fig. 33.

polarimeter *Polariscope*. An apparatus for measuring the rotation of the plane of vibration of polarized light by optically active substances. See *polarization of light* and *optical activity*.

polariscope See *polarimeter*.

polarization, angle of The *angle* of reflection from a *dielectric* medium, e.g. *glass*, at which the reflected ray is completely polarized, the plane of vibration being at right angles to the plane of incidence. See *polarization of light*.

polarization, electric See *electric polarization*.

polarization, electrolytic An increase in the electrical *resistance* of an *electrolyte* due to various causes; chiefly associated with the accumulation of gaseous *molecules* on the *electrodes* at which they are liberated.

polarization of light Ordinary *light* consists of electric (E) and magnetic (H) vibrations taking place in all possible *planes* containing the ray, the vibrations themselves being at right angles to the direction of the light path; i.e. light is a *transverse wave* motion. For each E vibration the associated H vibration takes place in a plane at right angles to it. In plane-polarized light, the E vibrations are confined to one plane, called the plane of vibration, and hence the associated H vibrations are also confined to one plane, the plane at right angles to this, called the plane of polarization. See also *circularly* and *elliptically polarized light*.

polar molecule A *molecule*, the configuration of *electric charge* in which constitutes a permanent electric *dipole*.

polarography A method of chemical analysis based on recording characteristic polarograms (curves representing variations of current strength with the applied voltage) for substances in solution. Compositions of solutions can be deduced from the form (characteristic "waves") of their polarograms.

Polaroid* Trade name of thin transparent films that produce plane-polarized light (see *polarization of light*) on transmission. They consist of thin sheets of *cellulose nitrate* packed with ultramicroscopic doubly-refracting crystals (see *double refraction*) with their *optic axes* parallel. The crystals produce plane-polarized light by differential absorption of the *ordinary* and *extraordinary rays*.

polaron An excitation in a solid consisting of polar molecules resulting from the interaction between an electron and its strain field. The presence of a polaron can be detected by irregularities in the shape of the conduction band.

pole, magnetic See *magnetic pole*.

pole of mirror See *mirrors, spherical*.

pole strength See *magnetic pole*.

polonium Po. Radium-F. A radioactive element decaying by *alpha-particle* emission. At. No. 84. It forms a stage in the radioactive disintegration of radium. The principal isotope has a mass number of 209 and a half-life of 103 years.

poly- Prefix denoting many, several, numerous.

polyamide A polymer in which the units are linked by *amide* or *thio-amide* groupings. See *nylon*.

polybasic An acid containing more than one atom of *acidic hydrogen* in a molecule.

polycarbonates Thermoplastic resins in which the structural units are linked through *carbonate radicals*. They usually consist of *polyesters* of *carbonic acids* and *dihydric phenols*. Their good dimensional stability and impact strength over a wide temperature range make them useful for electrical and other small components.

polychromatic Denoting *electromagnetic radiation* that consists of a mixture of *wavelengths*.

polycyclic Having more than one ring in a molecule.

polyene Any organic compound containing more than two double bonds.

polyester A polymer formed (usually) from a *polyhydric alcohol* and a *polybasic acid*. Used in the manufacture of synthetic resins, fibres, and plastics.

polyethylene See *polythene*.

polyethylene terephthalate Terylene*. Dacron*. A valuable polyester derived from *terephthalic acid* and *ethanediol* (ethylene glycol) by *esterification*, *condensation*, and *polymerization* reactions. Widely used for manufacture of synthetic fibres.

POLYGON

polygon A *plane* figure bounded by straight lines.

polygon of forces If any number of *forces*, acting on a particle, can be represented in magnitude and direction by the sides of a *polygon* taken in order, the forces will be in *equilibrium*.

polyhedron A solid figure having *polygons* for its faces. A regular polyhedron has all its faces equal in all respects; the five possible types of regular polyhedra are: (1) *tetrahedron*, 4 triangular faces; (2) *cube*, 6 square faces; (3) *octahedron*, 8 triangular faces; (4) *dodecahedron*, 12 five-sided faces; (5) *icosahedron*, 20 triangular faces.

polyhydric Containing more than one *hydroxyl* group in the *molecule*; e.g. ethylene glycol (*ethanediol*) and *glycerol* (1,2,3-propanetriol) are *polyhydric alcohols* (polyols).

polymer A product of *polymerization*: See also *atactic polymer*; *tactic polymer*.

polymerase An enzyme that catalyzes a biological *polymerization* reaction.

polymerization Originally, the chemical union of two or more *molecules* of the same *compound* to form larger molecules, resulting in the formation of a new compound of the same *empirical formula* but of greater *molecular weight*. E.g. *paraldehyde*, $(\text{CH}_3\text{CHO})_3$, is formed by the polymerization of *acetaldehyde*, CH_3CHO , and each molecule of the *polymer* is made up of three molecules of the *acetaldehyde monomer*. The meaning of the term has been extended to cover (1) 'addition polymerization', in which the molecule of the polymer is a multiple of the monomer molecule, as in the case of paraldehyde; (2) 'condensation polymerization', in which the monomer molecules are joined by *condensation* into a polymer molecule, which differs in empirical formula from the monomer; and (3) 'copolymerization', in which the polymer molecule is built up from two or more different kinds of monomer molecules. Many important products, such as *plastics* and textile fibres, consist of polymeric substances, either *natural* (e.g. *cellulose*), or *synthetic* (e.g. *nylon*).

polymethyl methacrylate Perspex*. A colourless, transparent, solid thermoplastic, produced by the *polymerization* of methyl methacrylate (see *methacrylic acid*), which is widely used because of its optical properties in place of *glass*.

polymorphism The existence of the same substance in more than two different crystalline forms.

polynomial (math.) An expression consisting of three or more terms.

polynucleotide A chain of *nucleotides* linked together as in a *nucleic acid*. *Ribonucleic acid* consists of a single chain, while *deoxyribonucleic acid* usually consists of a double *helix* comprising two polynucleotide chains.

polypeptide A chain of three or more *amino acids* each of which is joined to its neighbours by the *peptide* linkage. Polypeptide chains

may consist of up to several hundred amino acid units. *Proteins* consist of polypeptide chains cross-linked together in a variety of ways.

polyploidy Having more than twice the normal *haploid* number of *chromosomes* in a *cell*. Artificial polyploidy can be induced (e.g. by *colchicine*) and is used to produce fertile hybrids with desired characteristics.

polypropylene A colourless transparent thermoplastic material produced by the *polymerization* of *propylene*. Used where a flexible plastic material is required. It is similar to *polythene* but of greater strength.

polysaccharides A large class of natural *carbohydrates*. The *molecules* are derived from the *condensation* of several, frequently very many, molecules of simple *sugars* (*monosaccharides*). The class includes *cellulose* and *starch*.

polystyrene A thermoplastic material, produced by the *polymerization* of *styrene* ($C_6H_5CH:CH_2$), possessing good electrical insulating properties.

polytetrafluoroethylene PTFE. Teflon*. Fluon*. A thermoplastic produced by the *polymerization* of *tetrafluoroethylene* ($CF_2:CF_2$). Used to line saucepans and in bearings and electrical insulation because of its ability to withstand temperatures up to $400^\circ C$. and its low coefficient of friction.

polythene Polyethylene, Alkathene*. A tough waxy thermoplastic material, made by the addition *polymerization* of *ethylene*, C_2H_4 . Used as an insulating material and for many other purposes where a flexible, chemically resistant plastic material is required.

polyurethane See *urethane resins*.

polyvalent 1. Having more than one *valence*. 2. Having a valence of more than one. 3. (Of a *serum*). Containing more than one type of *antibody* and therefore effective against more than one type of *microorganism*.

polyvinyl acetate PVA. A colourless thermoplastic material, produced by the *polymerization* of *vinyl acetate* ($CH_2:CHOOC.CH_3$). Used in *adhesives*, *inks*, and *lacquers* for coating paper and fabric.

polyvinyl chloride PVC. A colourless thermoplastic material, produced by the *polymerization* of *vinyl chloride* ($CH_2:CHCl$), with good resistance to *water*, *acids*, *alkalis*, and *alcohols*.

polyvinylidene chloride A white thermoplastic material, produced by the *polymerization* of *vinylidene chloride* ($CH_2:CCl_2$). Also used as a copolymer with *acrylonitrile* or *vinyl chloride* giving products with a wide range of flexibilities.

polywater Anomalous water. A reported form of water differing in properties (*density*, *viscosity*) from normal water. There is now strong evidence that these properties are due to the presence of

POPULATION INVERSION

colloidal particles derived from impurities rather than to any differences in the molecular structure of the water itself.

population inversion The situation that exists in a *laser* when a large proportion of the emitting *ions* have been raised to an excited energy level by the process of optical pumping (i.e. introducing energy into the system by an external light source). This is an essential step in the process of stimulated emission. See also *maser*.

population type A classification of *stars* into two types: Population I consists of hot white young stars such as those that form the spiral arms of *spiral galaxies*; Population II consists of older stars, such as *red giants*, which are found at the centres of spiral galaxies.

porcelain A hard white material made by the firing of a *mixture* of pure kaolin (*china clay*) with *felspar* and *quartz*, or with other materials containing *silica*.

porphyrins A class of naturally occurring *pigments* derived from pyrrole. They include *chlorophyll* and the haem of *haemoglobin*. Their molecules are flat and contain a ring of 12 carbon and 4 nitrogen atoms; the latter are positioned so as to form a small square in the centre of the molecule (compare *phthalocyanines*) and are linked to a metal atom, forming a *chelate complex*. This metal is magnesium in chlorophyll, and iron in haem.

position circle A *circle* with its centre at an observed point and its radius such that the circumference passes through the place of observation. The portion of the circumference near the place of observation approximates to a *position line* if the radius is large.

position line A line of position on which the observer is situated at a given time. The intersection of two position lines, determined at the same time, fixes the position of the observer.

positive (math., phys.) In any convention of signs, regarded as being counted in the plus, or positive direction, as opposed to *negative*.

positive column A luminous region in a *discharge in gases* near to the positive *electrode*.

positive feedback See *feedback*.

positive magnetic pole The north-seeking pole of a *magnet*. See *magnetic pole*.

positive ray analysis See *mass spectrometer*.

positive rays Streams of *ions* bearing positive *electric charges*. They are produced by means of an electric discharge in a rarefied gas. See *discharge in gases*.

positron Positive *electron*. An *elementary particle* with the same mass as the electron and an *electric charge* of equal magnitude but opposite sign. Positrons are produced during several *decay processes* and during *pair production*; they do not themselves decay spontaneously but on passing through matter they collide with negative electrons as a result of which both particles are annihilated. See *annihilation radiation*.

- positronium** An unstable unit, resembling an *atom* of hydrogen, that consists of a *positron* (instead of a *proton*) and an *electron*. It decays by annihilation in less than 10^{-7} second into two or three *photons*.
- potash** An old name for *potassium carbonate*, *potassium hydroxide* (caustic potash), or any potassium salt.
- potassium** Kalium. K. Element. A.W. 39.102. At. No. 19. A silvery-white soft highly reactive *alkali metal*, strongly resembling sodium. R.d. 0.86, m.p. 62.3°C . Widely distributed in the form of various salts (e.g. *carnallite*), it is essential to life and is found in all living matter. Its salts used as *fertilizers*.
- potassium-argon dating** A method of *dating* geological specimens based on the decay of the *radioisotope* potassium-40 to argon-40. The *half-life* of potassium-40 is about 1.3×10^9 years and an estimate of the ratio of the two isotopes in a specimen gives an indication of its age.
- potassium bicarbonate** See *potassium hydrogen carbonate*.
- potassium bromide** KBr. A white crystalline salt, m.p. 730°C ., used in medicine and *photography*.
- potassium carbonate** Potash, carbonate of potash. K_2CO_3 . A white, very *soluble*, *deliquescent* salt, m.p. 891°C ., used in the manufacture of *glass* and *soap*.
- potassium chlorate** KClO_3 . A white crystalline *soluble* substance, m.p. 356°C ., used as an *oxidizing agent* and in the manufacture of fireworks.
- potassium chloride** Potassium muriate. KCl. A white crystalline *soluble* substance, m.p. 776°C ., used in medicine and as a *fertilizer*.
- potassium dichromate** Dichromate or bichromate of potash. $\text{K}_2\text{Cr}_2\text{O}_7$. A red crystalline *soluble* salt, m.p. 398°C ., prepared from *chrome iron ore*. Used as an *oxidizing agent*, and in the *paint* and *dye* industries.
- potassium ferricyanide** $\text{K}_3\text{Fe}(\text{CN})_6$. A red *soluble* crystalline substance, used in the manufacture of *pigments* and *paper*.
- potassium ferrocyanide** $\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$. A yellow *soluble* crystalline substance, used as a *dye* and in case-hardening.
- potassium hydrogen carbonate** Potassium bicarbonate. KHCO_3 . A white *soluble* substance, used in cooking and as an *antacid*.
- potassium hydrogen difluoride** Acid potassium fluoride. KHF_2 . A *deliquescent* crystalline substance used in the manufacture of fluorine.
- potassium hydrogen tartrate** Cream of Tartar. $\text{C}_4\text{O}_6\text{H}_5\text{K}$. A white crystalline powder obtained from *argol* (tartar), used in *baking powder*.
- potassium hydroxide** Caustic potash. KOH. A white *deliquescent solid*, m.p. 360.4°C ., that dissolves in *water* to give an *alkaline solution*. Used in medicine and in the manufacture of *soap*.

POTASSIUM IODIDE

- potassium iodide** KI. A white crystalline *soluble* substance, m.p. $686^{\circ}\text{C}.$, used in *photography* and in *medicine*.
- potassium nitrate** Nitre, saltpetre. KNO_3 . A white *soluble* crystalline salt, m.p. $336^{\circ}\text{C}.$, that acts as an *oxidizing agent* when hot. Used in *medicine*, for pickling meat, and in *gunpowder*.
- potassium permanganate** Permanganate of potash: KMnO_4 . A deep purple, crystalline, *soluble salt*. Dissolved in water it gives a purple solution that acts as a powerful *oxidizing agent*. Used as a *disinfectant* and in *volumetric analysis*.
- potassium sodium tartrate** Rochelle salt. $\text{COOK}(\text{CHOH})_2\text{COONa} \cdot 4\text{H}_2\text{O}$. A white crystalline *soluble salt*, m.p. $70\text{--}80^{\circ}\text{C}.$, used in the preparation of *baking powder*, Seidlitz powders, etc.
- potassium sulphate** K_2SO_4 . A white *soluble* crystalline substance, m.p. $1069^{\circ}\text{C}.$, used in *fertilizers* and mineral waters.
- potassium thiocyanate** KSCN. A colourless *hygroscopic* substance, m.p. $173.2^{\circ}\text{C}.$, used in the manufacture of *dyes* and *drugs*.
- potential** See *electric potential*.
- potential barrier** See *nuclear barrier*.
- potential difference** If two points have a different *electric potential* there is said to be a potential difference (p.d.) between them; if the points are joined by an *electric conductor*, an *electric current* will flow between them. Potential difference is defined as the *work* performed when a unit positive *electric charge* is moved from one of the points to the other. See also *electromotive force*, E.M.F. The practical unit of p.d. and E.M.F. is the *volt*.
- potential energy** The *energy* that a body possesses by virtue of its position. E.g. a coiled spring, or a vehicle at the top of a hill, possesses potential energy. It is measured by the amount of *work* the body performs in passing from that position to a standard position in which the potential energy is considered to be zero. The potential energy of a *mass*, m , raised through a height, h , is mgh , where g is the *acceleration of free fall*.
- potential series** See *electromotive series*.
- potentiometer** 1. An instrument for measuring *direct current* E.M.F. or *potential differences*, which does not draw current from the circuit containing the E.M.F. to be measured. In its simplest form it consists of a uniform *resistance* AB (see Fig. 34) in the form of a single wire, connected to a source of E.M.F., E . A slide wire contact C is connected, in series with a sensitive *galvanometer* G, to one terminal of the E.M.F. to be measured. The other terminal is connected to A, so that the E.M.F.s across XY and AC are in opposition through G. Contact C is then adjusted until no current flows through the galvanometer. The required E.M.F. is then given by $E l_1 / L$, where L is the total length of the resistance AB, and l_1 is the length AC for zero current through G. 2. A *voltage divider*.

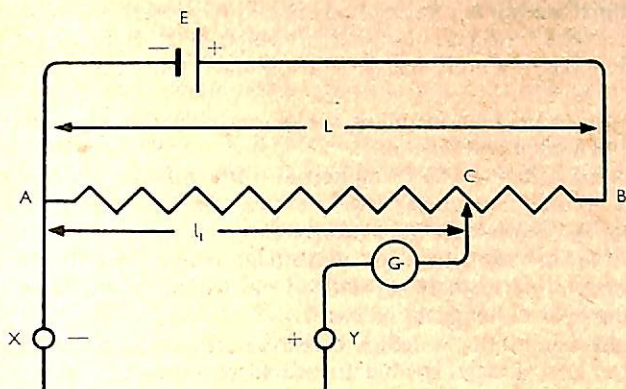


Figure 34.

pound British unit of *weight*. It was formerly defined as the weight, in vacuo, of a platinum cylinder called the Imperial Standard Pound. The pound was redefined by statute in 1963 as 0.453 592 37 kilogram. Used as a unit of *force*, i.e. the force of attraction of the Earth upon a mass of one pound, and as a unit of mass.

poundal Unit of *force* in the *f.p.s.* system. The force that, acting on a mass of 1 pound, will impart to it an *acceleration* of 1 foot per second per second. It is approximately 1/32 of a force of 1 pound weight.

powder metallurgy The science or practice of manufacturing small metal articles by sintering powdered metals under *heat* and *pressure*.

power (math.) A quantity successively multiplied by itself is said to be raised to a power, the magnitude of the power being the number of times that the quantity occurs in the multiplication. Thus $2 \times 2 \times 2 \times 2$ is 2 raised to the fourth power, 2 to the fourth, denoted as 2^4 , 4 being the *index* or *exponent*.

power (phys.) Rate of doing work. Measured in units of work per unit time. The derived *SI* unit of power is the watt. See also *horsepower*.

power alcohol Industrial *ethanol* used as a *fuel*.

power factor In an electrical circuit, the ratio of the power dissipated, P , to the product of the *electromotive force*, E , and the *current*, I . In single-phase and three-phase circuits the power factor is given by $\cos \phi$, where ϕ is the *phase angle* between the E.M.F. and the current, i.e. $P = EI \cos \phi$.

power reactor See *nuclear reactor*.

praseodymium Pr. Element. A.W. 140.907. At. No. 59. R.d. 6.78, m.p. 935°C. See *lanthanides*.

PRECESSIONAL MOTION

- precessional motion** A rotating body is said to precess when, as a result of an applied *couple*, the axis of which is at right angles to the rotation axis, the body turns about the third mutually perpendicular axis.
- precipitate** (chem.) An *insoluble* substance formed in a *solution* as the result of a *chemical reaction*.
- precipitation** (chem.) The formation of a *precipitate*. A common type of precipitation much used in chemical analysis and preparations, occurs by *double decomposition* when two *solutions* are mixed if each of the solutions contains one *radical* of an *insoluble compound*.
- precursor** An intermediate substance from which another is formed in the course of a chemical process.
- presbyopia** Long sight. A defect of vision normally occurring in elderly people. The subject is able to see distant objects clearly, but is unable to accommodate the eye to see near objects distinctly. It is corrected by the use of *convex spectacle lenses*.
- pressure** The force per unit area acting on a surface. 'Absolute pressure' is the pressure measured with respect to zero pressure. 'Gauge pressure' is the pressure measured by a gauge in excess of the pressure of the *atmosphere*. The *SI unit* of pressure is the *pascal* (N m^{-2}). The *c.g.s. system* uses the *dyne per square centimetre* ($1 \text{ Pa} = 10 \text{ dynes cm}^{-2}$). Other units are the *bar* ($= 10^5 \text{ Pa}$), the *atmosphere* ($= 101\,325 \text{ Pa}$), the *mmHg* ($= 133.322 \text{ Pa}$). See also Appendix, Table 1.
- pressurized water reactor** PWR. A *nuclear reactor* in which water is the coolant and the *moderator*, but in which the water is maintained at a high pressure in order to prevent it *boiling*. The pressurized water is passed through a *heat exchanger* to generate *steam* for producing *electric power* in a conventional *turbo-generator*.
- primary cell** Voltaic cell. Galvanic cell. A device, usually irreversible, for producing an *electromotive force* and delivering an *electric current* as the result of a *chemical reaction*. See *Daniell cell*; *Leclanché cell*; *Weston cell*; *mercury cell*.
- primary coil** The input coil of a *transformer* or *induction coil*.
- primary colours** (phys.) Red, green, and a bluish-violet. Any colour may be obtained by suitably combining *light* producing these (see *colour vision*). Also the *pigment colours* red, yellow, and blue, which cannot be imitated by mixing any other pigment colours.
- prime number** (math.) A number possessing no *factors* (i.e. divisible by no whole number, other than itself and one).
- principal axis** See *optical axis*.
- principal focus** See *mirrors, spherical*; *lens*.
- principal plane** (phys.) In a *crystal* exhibiting *double refraction*, a principal plane is a *plane* containing the *optic axis* and either the *ordinary ray* (principal plane of ordinary ray) or the *extraordinary ray* (principal plane of extraordinary ray).

- principal point** (phys.) Two points on the *optical axis* of a thick *lens* or combination lens system, such that if the object distance is measured from one and the image distance from the other, the *equations* obtained relating object-image distance, etc., are similar to those obtained for a thin lens.
- principal section** (phys.) A principal section of a *crystal* exhibiting *double refraction* is a *plane* passing through the *optic axis* and at right angles to one of the crystal surfaces.
- principle of superposition** See *Huygens principle of superposition*.
- printed circuit** An *electronic circuit* in which the wiring between components, and certain fixed components themselves, are printed on to an insulating board. The board is coated with copper and the portion of the metal that represents the wiring or components is photographically covered with a protective film, the rest of the metal being etched away in an *acid bath*.
- prism** (math.) A solid figure having two identically equal faces (bases) consisting of *polygons* in parallel *planes*; the other faces being *parallelograms* equal in number to the number of sides of one of the bases.
- prism, optical** A triangular *prism* made of material *transparent* to the *light* being used; e.g. *glass* for visible light, *quartz* for *ultraviolet* and near *infrared radiation*.
- prismatic** In the shape of a *prism*.
- prismatic optical instruments** Instruments (field-glasses, etc.) in which a right-angled *prism* is used to invert the inverted image produced by the *objective*.
- probability, mathematical** A mathematical expression of the chance that a specified event will occur. If the event is certain to occur the probability is 1; if it is certain not to occur the probability is 0. Between these two extremes the probability of an event occurring is expressed as a number between 0 and 1. For example, if an event can happen in *a* ways and fail in *b* ways, and, except for the numerical difference between *a* and *b*, is as likely to happen as to fail, the mathematical probability of its happening is $a/(a + b)$ and of its failing, $b/(a + b)$.
- probability distribution of electrons** The *probability* that an *electron* within an *atom* will be at a certain point in *space* at a given time; it is determined by the magnitude of the square of the *wave function*.
- process control** The control of complex industrial or chemical processes by *electronic* means.
- producer gas** A *fuel gas* produced by the partial combustion of *coke* or *coal* in a restricted supply of air, to which *steam* may have been added. The principal constituents of the gas are *carbon monoxide* (25%-30%), *nitrogen* (50%-55%), and *hydrogen* (10%-15%). *Hydrocarbons* and *carbon dioxide* will also be present.

PRODUCT

product (math.) The product of two or more quantities is the result of multiplying them together.

production reactors See *nuclear reactor*.

progesterone $C_{21}H_{30}O_2$. A white crystalline *steroid hormone*, m.p. $128.5^\circ C.$, responsible for preparing the reproductive organs of mammals for pregnancy and for protecting the embryo.

program Programme. The sequence of instructions fed into a *computer* in order to enable it to carry out a process.

projectile A body that is thrown or projected. If the projectile is discharged with a *velocity* v at an *angle* a to the horizontal, the following formulae hold true if the resistance of the air is neglected (g being the *acceleration of free fall*):

$$\begin{aligned}\text{Time to reach highest point of flight} &= (v \sin a)/g \\ \text{Total time of flight} &= (2v \sin a)/g \\ \text{Maximum height} &= (v^2 \sin^2 a)/2g \\ \text{Horizontal range} &= (v^2 \sin 2a)/g\end{aligned}$$

prolate spheroid See *spheroid*.

proline A white, crystalline *amino acid*, m.p. $220^\circ C.$, that occurs in most *proteins*. See Appendix, Table 5.

promethium Pm. A *radioactive element* of the *lanthanide series*. At. No. 61. M.p. $1035^\circ C.$, b.p. $2460^\circ C.$ It occurs as a fission product of uranium in *nuclear reactors*. The most stable *isotope*, $^{145}_{61}\text{Pm}$, has a *half-life* of about eighteen years.

prompt critical Capable of sustaining a *nuclear fission chain reaction* on the *prompt neutrons* alone, without contribution from *delayed neutrons*.

prompt neutrons *Neutrons* resulting from *nuclear fission* (either during the fission process or from freshly formed fission fragments) that are emitted without measurable delay, i.e. in less than a millionth of a second. See *delayed neutrons*.

proof spirit *Ethanol* containing 49.28% alcohol by *weight*, or 57.10% by *volume*, and having a *relative density* of 0.919 76 at $60^\circ F.$ Formerly defined as the weakest solution of alcohol that would fire *gunpowder* when brought into contact with it and ignited.

proof spirit, degrees The number of degrees under proof is the *volume* percentage of *water* in a *solution* regarded as containing *proof spirit* and *water*; degrees over proof is the volume increase obtained when 100 volumes of the spirit are diluted with sufficient *water* to obtain *proof spirit*. Spirits are usually sold on the basis, '30° under proof' or '70° proof' both of which mean the same. Such spirit contains $57.1 \times 70/100 = 39.97\%$ alcohol by volume.

propane C_3H_8 . The third *hydrocarbon* of the *alkane series*. An inflammable gas. B.p. $-42.17^\circ C.$ Used as a *fuel*.

propanol Propyl alcohol. Either of two isomers (see *isomerism*). 1. 1-Propanol, *n*-propyl alcohol, $CH_3CH_2CH_2OH$, a colourless liquid,

b.p. $97.2^{\circ}\text{C}.$, used as a *solvent*. 2. 2-Propanol, isopropyl alcohol, $\text{CH}_3\text{CHOHCH}_3$, a colourless *liquid*, b.p. $82.4^{\circ}\text{C}.$, used for the industrial production of *acetone*, as a *solvent*, and as an intermediate in organic *synthesis*.

propanone See *acetone*.

propellant 1. The explosive substance used to fill cartridges, shell cases, and *solid fuel rockets*. The term is also used to include the fuel and *oxidant* of rockets when these are separate. 2. A gas used in *aerosol* preparations to expel the *liquid* contents through an atomizer.

propene Propylene. $\text{CH}_2=\text{CH}.\text{CH}_3$. The second member of the *alkene* series of *hydrocarbons*. A colourless gas, b.p. $-47^{\circ}\text{C}.$ See also *polypropylene*.

proper fraction A fraction in which the *numerator* is less than the *denominator*, e.g. $3/4$. In an 'improper fraction' the numerator is greater than the denominator, e.g. $4/3$.

proper motion of a star The component of a *star's* motion in *space* relative to the *Sun* that is perpendicular to the line of sight.

propionaldehyde Propanal. Propyl aldehyde. $\text{CH}_3\text{CH}_2\text{CHO}$. A colourless *liquid aldehyde*, b.p. $48.8^{\circ}\text{C}.$, used in the manufacture of *plastics*.

proportion (math.) An equality between two *ratios*. If $a/b = c/d$, the four quantities, *a*, *b*, *c*, *d* are in proportion.

propulsion reactor See *nuclear reactor*.

propyl The univalent alkyl radical C_3H_7- .

propylene See *propene*.

prosthetic group A non-*protein* group combined to a protein, e.g. the haem group in *haemoglobin* or the *nucleic acid* in *nucleoprotein*.

protactinium Pa. Radioactive element. At. No. 91. The most abundant natural *isotope* has a *mass number* of 231 and a *half-life* of 32 480 years.

protargol A powder containing finely divided silver and *protein*; with *water*, it forms a *colloidal solution* of silver.

proteases Proteinases. A group of *enzymes* capable of breaking up *proteins* into *amino acids*, of building up amino acids into proteins, and of substituting one amino acid for another in protein *molecules*. Occurring in all living tissues, they conduct the processes of protein *metabolism* in the living *organism*.

proteins A class of complex nitrogenous *organic compounds* of high *molecular weight* (18 000–10 000 000), which are of great importance to all living matter. Protein *molecules* consist of hundreds or thousands of *amino acids* joined together by the *peptide* linkage into one or more inter-linked *polypeptide* chains, which may be folded in a variety of different ways. Some twenty different amino acids occur in proteins and each protein molecule is likely to contain all of them arranged in a variety of sequences. It is the sequence of the different amino acids that gives individual proteins

PROTEOLYTIC

- their specific properties. The particular sequence of the amino acids in proteins, which are synthesized in the *cytoplasm*s of *cells*, is determined by the sequence of the *nucleotides* in the *nucleic acids* of the *chromosomes*, three nucleotides coding for each amino acid. Most proteins form *colloidal solutions* in water or dilute salt solutions, but some (notably the fibrous proteins) are *insoluble*. Proteins may be simple, i.e. yielding only amino acids on *hydrolysis*, others are 'conjugated', i.e. combined with other substances (see *prosthetic groups*). *Enzymes* are a particularly important group of proteins as they determine the *chemical reactions* that will take place in a cell, and therefore the characteristics that it will have.
- proteolytic** Proteoclastic. Having the power of decomposing or *hydrolyzing proteins*.
- protium** The hydrogen *isotope* with *mass number* of one.
- protolysis** A reaction involving the transfer of *protons* (*hydrogen ions*).
- proton** A stable *elementary particle* with *electric charge* equal in magnitude to that of the *electron* but of opposite sign, and with *mass* 1836.12 times greater than that of the electron ($1.672\,614 \times 10^{-27}$ kilogram). The proton is a *hydrogen ion* (i.e. a normal hydrogen atomic *nucleus*) and is a constituent of all other atomic nuclei. See *atom*, *structure of*.
- proton number** See *atomic number*.
- protoplasm** The *matter* of which biological *cells* consist.
- protostar** A developing *star* consisting of condensing interstellar gas and dust.
- provitamin** A substance from which a *vitamin* is formed.
- Prussian blue** Potassium *ferric ferrocyanide*, $\text{KFe}[\text{Fe}(\text{CN})_6]$. A deep blue substance obtained by the action of a ferric salt on *potassium ferrocyanide*.
- prussic acid** An intensely poisonous solution of *hydrocyanic acid*, HCN.
- pseudo-aromatic** A ring compound containing *conjugated double bonds* in the manner of an *aromatic compound*, although its properties are different to those of an aromatic compound.
- pseudo-scalar** A *scalar quantity* that changes sign in the transition from a right-handed to a left-handed system of coordinates.
- pseudo-vector** Axial vector. A *vector quantity* that changes sign in the transition from a right-handed to a left-handed system of coordinates.
- psi particle** J particle. A *meson* that has no charge but an anomalously long lifetime. The discovery of this particle in 1974 led to the extension of the *quark model* and the hypothesis that a fourth quark (and its antiquark) existed with a new property called *charm*. The psi particle is now believed to consist of the charmed quark plus its antiquark (i.e. $c\bar{c}$).

psychrometry The measurement of the *humidity of the atmosphere*.

ptomaines A class of extremely poisonous *organic compounds* formed during the putrefaction of *proteins* of animal origin. Food poisoning, frequently misnamed ptomaine poisoning, is almost invariably due to causes other than the ptomaines.

ptyalin An *enzyme* that occurs in the saliva and serves to convert *starch* into *sugar*.

P-type conductivity See *N-type conductivity*.

puddling process The preparation of nearly pure *wrought iron* from *cast iron* that contains a high percentage of carbon. The cast iron is heated with *haematite*, Fe_2O_3 , the oxygen in which oxidizes the carbon.

pulsars *Stars* that emit *radio frequency electromagnetic radiation* in brief *pulses* at extremely regular intervals. Many such objects have been located by *radio telescopes*, a few of them have also been observed to emit pulses of light. It has been suggested that pulsars are *neutron stars*, emitting pulses of radiation as they rotate.

pulse A brief increase in the magnitude of a quantity whose value is usually constant (e.g. *current* or *voltage*).

pulse height analyser. An instrument incorporating an *electronic* circuit that permits only *voltage pulses* of predetermined *amplitudes* to be passed to succeeding circuits. The range of amplitudes passed through such circuits is referred to as the 'channel width' or 'window'. In a single-channel analyser the channel width is usually pre-set and the *threshold* varied to scan the amplitude spectrum of incoming pulses. In a multi-channel instrument, often called a 'kicksorter', the incoming pulses are sorted and recorded according to their amplitudes. The kicksorter is used for distinguishing between *isotopes* by sorting the characteristic 'kicks' that their *radiations* give.

pulse-jet A type of *ram-jet* in which the *combustion* process is not continuous, but is arranged to occur at intervals between which the *pressure* in the combustion chamber is allowed to build up. The German 'flying bombs' of World War II were powered by pulse-jets fitted with air intake valves that opened when the pressure resulting from the passage of the projectile through the air exceeded the pressure in the combustion chamber: each new charge being separately fired.

purine $\text{C}_5\text{H}_4\text{N}_4$. A white crystalline *organic base*, m.p. 216°C ., related to *uric acid*. *Derivatives* are of great importance biologically as they occur in *adenosine triphosphate* and *nucleic acids*. *Adenine* and *guanine* are typical of such derivatives.

purple of cassius A purple *pigment*, consisting of a *mixture* of colloidal gold and *stannic acid*. Used for making *ruby glass*.

push-pull Denoting an *electronic circuit* in which two components are out of phase by 180° . E.g. a push-pull valve *amplifier* has two *valves*

PUTREFACTION

arranged so that the *control grid* input signals are 180° out of phase, the output circuits being arranged to combine the two signals so that they are in phase.

putrefaction Chemical *decomposition*, by the action of *bacteria*, of the bodies of dead animals and plants; especially the *decomposition* of *proteins* with the production of offensive substances.

putty A material composed of powdered *chalk* mixed with *linseed oil*.

putty powder Impure tin oxide, SnO_2 .

pycnometer An apparatus for determining the *density* and coefficient of *expansion* of a *liquid*. It consists of a glass vessel graduated to hold a definite *volume* of liquid at a given *temperature*. By weighing it full of liquid at different temperatures, the variations in density, and therefore the apparent expansion, may be found.

pyramid (math.) A solid figure having a *polygon* for one of its faces (the base), the other face being *triangles* with a common *vertex*. The *volume* of a pyramid is one-third of the *product* of the area of the base and the vertical height.

pyrene 1. $\text{C}_{16}\text{H}_{10}$. A yellow, crystalline *polycyclic hydrocarbon*, m.p. 149°C ., found in *coal-tar*. **2.** Trade name for a *fire extinguisher* consisting of *carbon tetrachloride*, CCl_4 .

Pyrex* A type of *glass* that is resistant to heat and chemical attack; it is widely used in laboratory glassware.

pyridine $\text{C}_5\text{H}_5\text{N}$. A colourless *heterocyclic liquid* with an unpleasant smell. B.p. 115°C . It occurs in *bone-oil* and *coal-tar*. Used for making *methyated spirit* unpalatable; *compounds* derived from it are used in medicine.

pyridoxine Vitamin B_6 . $\text{C}_8\text{H}_{11}\text{NO}_3$. A *pyridine derivative* that is a member of the *vitamin B* complex; it is believed to be of importance in the utilization of *unsaturated fatty acids* by many *organisms*.

pyrimidine $\text{C}_4\text{H}_4\text{N}_2$. An *organic base*, m.p. 22°C ., b.p. 123.5°C ., consisting of a *heterocyclic six-membered ring*. *Derivatives* are of great biological importance as they occur in *nucleic acids*. *Uracil*, *thymine*, and *cytosine* are typical of such derivatives.

pyrites Natural *sulphides* of certain *metals*. Iron pyrites (fools' gold) is FeS_2 ; copper pyrites is CuFeS_2 .

pyro- Prefix denoting fire, strong heat. In chemical nomenclature it denotes a substance obtained by heating; e.g. *pyroboric acid*, obtained by heating *boric acid*. It is also used to indicate that the *water content* of an *acid* or *salt* is intermediate between that of the *ortho-* and *meta-* *compounds* of the same name.

pyrocatechol Catechol. 1,2-Dihydroxybenzene. $\text{C}_6\text{H}_4(\text{OH})_2$. A solid *dihydric phenol*, m.p. 105°C ., used in photography.

pyroelectricity The property of certain *crystals*, e.g. *tourmaline*, of acquiring *electric charges* on opposite faces when the crystals are heated.

pyrogallol Pyrogalllic acid, 1, 2, 3-trihydroxybenzene. $C_6H_3(OH)_3$. A white crystalline *soluble solid*, m.p. $132^\circ C.$, that is a powerful *reducing agent*; *alkaline solution* rapidly absorbs oxygen. Used in photographic *developing* and in gas analysis for the estimation of oxygen. See *Orsat apparatus*.

pyroligneous acid A watery *liquid* obtained by the *destructive distillation* of wood. It contains *acetic acid*, CH_3COOH , *methanol*, CH_3OH , *acetone* $(CH_3)_2CO$, and small amounts of other *organic compounds*.

pyrolusite Natural *manganese dioxide*, MnO_2 . A black crystalline *solid*, r.d. 4.8; the principal *ore* of manganese.

pyrolysis Chemical *decomposition* by the action of *heat*.

pyrometers Instruments for measuring high *temperatures*. The four main types are: (1) platinum resistance *thermometers*, which make use of the increased electrical *resistance* of platinum wire with rise in temperature; (2) thermoelectric thermometers, using the principle of the *thermocouple*; (3) optical pyrometers, in which the temperature is estimated by the intensity of the *light* emitted by the body in a narrow *wavelength* range; and (4) *radiation* pyrometers, which detect the *heat* radiation from the hot body (see *radiometer*).

pyrophoric alloys *Alloys* that emit sparks when scraped or struck, and are therefore used as 'flints' in lighters. See *Misch metal*; *Auer metal*.

pyrophosphoric acid $H_4P_2O_7$. A crystalline *soluble* substance, m.p. $61^\circ C.$, formed from *phosphorus pentoxide* and two *molecules* of *water*.

pyrosulphuric acid $H_2S_2O_7$. A highly corrosive *hygroscopic* crystalline *solid*, m.p. $35^\circ C$.

pyrotechnics Fireworks.

pyroxine A group of *minerals* consisting principally of *silicates* of magnesium, iron, and calcium.

pyrrole C_4H_5N . A colourless liquid *heterocyclic compound*, b.p. $103^\circ C.$, found in coal tar.

pyruvic acid $CH_3.CO.COOH$. A *liquid organic acid*, m.p. $13^\circ C.$, of importance in the metabolic (see *metabolism*) breakdown of *glucose*. Pyruvic acid is itself broken down in the *citric acid cycle*.

Pythagoras, theorem of In a right-angled *triangle* the square on the *hypotenuse* is equal to the sum of the squares on the other two sides. Named after the Greek mathematician (c. 582-500 B.C.).

Q

QSG Quasi stellar galaxy. A *quasar* that is not a radio source.

quadrant Quarter-circle. A *sector* of a *circle* bounded by an arc and two radii at right angles.

quadratic equation An *equation* involving the *square* or second power of the unknown quantity; satisfied by two values (known as *roots*) of the unknown quantity. Any quadratic equation may be written in the form

$$ax^2 + bx + c = 0;$$

the roots of this equation are given by the expression

$$x = [-b \pm \sqrt{(b^2 - 4ac)}]/2a.$$

The sum of the roots is $-b/a$ and their products is c/a .

Thus any quadratic equation may be solved by substitution of the appropriate values in the above expressions.

quadrature The position of the *Moon* or outer *planet* such that a line between it and the *Earth* makes a right angle with a line joining the *Earth* to the *Sun*.

quadrilateral A *plane* figure bounded by four straight lines.

quadrivalent Tetravalent. Having a *valence* of four.

qualitative Dealing only with the nature, and not the amounts, of the substances under consideration.

qualitative chemical analysis The determination of the chemical nature of substances; identification of substances present in a *mixture*.

quality control The application of the theory of mathematical *probability* to sampling the output of an industrial process, with the object of detecting and controlling any variations in quality.

quality of sound Most sounds are not 'pure'; i.e. they are composed of vibrations of more than one *frequency*. A note consists of a 'fundamental', of greatest intensity and lowest *pitch*; and several *overtones*, of much lesser intensity and of frequencies that are simple multiples of that of the fundamental. The various overtones produce a characteristic quality or timbre in the note.

quantitative Dealing with quantities as well as the nature of the substances under consideration.

quantitative chemical analysis The determination of the amounts of substances present, by chemical means.

quantity of electricity The amount of electricity flowing through a circuit; the product of the current and the time for which it flows. The *SI unit* is the *coulomb*.

quantized A quantity is said to be quantized if, in accordance with *quantum mechanics*, it can only have certain discrete values (each of which is called a *quantum*). Such a quantity cannot vary continuously, differences in value being separated by 'jumps'.

quantum According to the *quantum theory*, *energy* exists in discrete units, only whole numbers of which can exist: each unit is called a quantum (plural 'quanta'). The quantum of *electromagnetic radiation* is the *photon*; in certain contexts the quantum of energy associated with *nuclear forces* may be taken as the *meson*.

quantum electrodynamics The study of *electromagnetic interactions* in terms of *quantum theory*.

quantum electronics The study of the generation or amplification of *microwave power* in *solid crystals*, in accordance with the laws of *quantum mechanics*.

quantum mechanics The system of mechanics that, during the present century, has replaced *Newtonian mechanics* as a method of interpreting physical phenomena occurring on a very small scale (e.g. the motion of *electrons* and *nuclei* within *atoms*; see *atom, structure of*). Quantum theory originated with the discovery by Max Planck that the *heat radiation* from a black-body (see *black-body radiation*) is *quantized*, i.e. emitted in discrete *quanta* of *energy*, the magnitudes of which are given by the product of the frequency of the radiation and a universal constant, now known as *Planck's constant*. It was soon realized that all *electromagnetic radiations* are quantized (see *photon*) and the theory was developed by Niels Bohr so that the *spectrum* of hydrogen could be accounted for *quantitatively* (see *Bohr theory*). This early version of quantum mechanics was refined by Sommerfeld to take into account the elliptical *orbits* of electrons. More recently quantum mechanics has been developed in a specialized form, known as *wave mechanics*, which is more versatile and involves fewer arbitrary assumptions than the original theory.

quantum numbers *Integral* or half-integral numbers that specify the state of a system or its components in *quantum mechanics*. An *electron* within an *atom*, for example, is specified by four quantum numbers in the *Bohr theory*: (1) the principal quantum number, n , defining the *energy level* or *shell* in which the electron occurs; (2) the azimuthal quantum number, l , defining the shape and multiplicity of the orbit within that shell; (3) the magnetic orbital quantum number, m_l , which determines the orientation of the orbit with reference to a strong magnetic field; and (4) the magnetic *spin* quantum number, m_s , which determines the direction of spin of an electron in a magnetic field. See also *Pauli's exclusion principle*.

quantum theory The theory that grew up around Planck's introduction into *physics* of the concept of the discontinuity of *energy*. The

QUARKS

system of *quantum mechanics* evolved from this theory during the first half of the twentieth century.

quarks Originally three hypothetical *elementary particles*, with corresponding antiparticles, postulated by Murray Gell-Mann to account for the composition of *hadrons*. Since the discovery of the *psi particle* the number of quarks has been increased to four, i.e. u (up), d (down), s (strange), c (charm). See *strangeness*; *charm*. *Mesons* are believed to consist of a quark and an antiquark (e.g. the pion π^+ consists of $u\bar{d}$, the phi meson consists of $s\bar{s}$, and the psi particle of $c\bar{c}$). *Baryons* are thought to consist of three quarks bound together (e.g. the *proton* consists of uud and the *neutron* of udd). Quarks would have fractional electronic charges (i.e. $u + 2/3$, d and $s - 1/3$). According to the quark theory all matter consists either of quarks or *leptons*, which are the only true elementary particles; however no quarks have yet been identified experimentally.

quart Unit of capacity equal to one quarter of a *gallon*.

quarter-wave plate A plate of doubly refracting material (see *double refraction*) cut parallel to the *optic axis* of the *crystal*, and of such a thickness that a *phase difference* of $\pi/2$ or 90° is introduced between the *ordinary* and *extraordinary rays* for *light* of a particular *wavelength* (usually sodium light). Plane-polarized light (see *polarization of light*) incident normally upon such a plate, with its plane of vibration making an angle of 45° with the optic axis, emerges from the plate *circularly polarized*. A quarter-wave plate is often used in the analysis of polarized light.

quartz Natural crystalline *silica*, SiO_2 , which sometimes occurs in clear, colourless *crystals* (*rock crystal*); more frequently it occurs as a white, *opaque* mass. Quartz crystals exhibit the *piezoelectric effect* to a marked extent.

quartz clock A clock regulated by a *quartz crystal*, which vibrates with a definite constant *frequency* under the effect of an alternating *electric field* tuned to this *resonance frequency* of the crystal. (See *piezoelectric effect*.) Being much more accurate than a pendulum-regulated clock, it is used for astronomical and other very precise work.

quasars Quasi stellar radio sources. Recently discovered extra-galactic sources of high energy *electromagnetic radiation*. They were originally located by radio astronomers (see *radio astronomy*) because of their powerful *radio frequency* emissions. Several hundred of these objects have now been observed, some of them are also visible with *optical telescopes* as they emit *light*. If their observed *red-shifts* are interpreted as high *velocities* of recession, their enormous *energy* outputs cannot be explained by any known process.

quaternary ammonium compounds *Compounds of the general formula NR_4OH ; they are theoretically derived from ammonium hydroxide, NH_4OH , by replacement of the hydrogen atoms by organic radicals.*

quenching The process of terminating the discharge in a *Geiger counter* by preventing re-ignition.

quenching of steel Rapid cooling by immersion into water or oil, to harden the steel.

quicklime See *calcium oxide*, CaO .

quicksilver See *mercury*.

quiet Sun The Sun's condition when no *sunspots*, *solar flares*, or *solar prominences* are taking place. *Radio frequency emission* (see *radio astronomy*) from the Sun, which has to be observed during the rare periods of the quiet Sun, has enabled temperature measurements of the various layers of the solar atmosphere to be made.

quinhydrone $\text{C}_6\text{H}_4(\text{OH})_2 \cdot \text{C}_6\text{H}_4\text{O}_2$. An addition compound of *hydroquinone* and *quinone*. A green crystalline substance, m.p. 171°C ., used in *photography* and as an *antioxidant*; the quinhydrone electrode is used in pH measurement.

quinidine $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$. A colourless crystalline *alkaloid*, isomeric with *quinine*, m.p. $174\text{--}5^\circ\text{C}$., used in medicine.

quinine $\text{C}_{20}\text{H}_{24}\text{O}_2\text{N}_2 \cdot 3\text{H}_2\text{O}$. A colourless bitter-tasting crystalline *alkaloid* that occurs in *Cinchona bark*, m.p. 57°C . Used in the treatment of malaria.

quinol See *hydroquinone*.

quinoline $\text{C}_9\text{H}_7\text{N}$. A colourless liquid base, b.p. 237°C ., that occurs in coal-tar. Used as a solvent and in the manufacture of dyes.

quinones A series of aromatic compounds in whose molecules two hydrogen atoms in the same benzene nucleus are replaced by oxygen atoms, forming carbonyl groups. The quinones are therefore diketones (see *ketones*). The simplest member of the series is *p*-quinone (*p*-benzoquinone), $\text{O}:\text{C}_6\text{H}_4:\text{O}$; a yellow crystalline solid, m.p. 115.7°C ., used as an oxidizing agent, in dye manufacture, and in photography.

quintivalent Pentavalent. Having a valence of five.

quotient See *division*.

Q-value Nuclear energy change, nuclear heat of reaction. The net amount of energy released in a nuclear reaction; usually expressed in million electron-volts, *MeV*, per individual reaction.

R

racemic acid Racemic tartaric acid, *dl*-tartaric acid. The *racemic form* of tartaric acid.

racemic form An isomeric form of a substance that exhibits *stereoisomerism*. It consists of an *equimolecular mixture* of the two *optically active* forms. Such a racemic form is denoted by the letters *dl.*, e.g. *dl*-tartaric acid; it is optically inactive and is said to be externally compensated.

rad The unit of absorbed dose of *ionizing radiation*. One rad is equal to the energy absorption of 100 ergs per gram (0.01 J kg^{-1}) of irradiated material.

radar An abbreviation of the words RADIO DETECTION AND RANGING. It covers any system employing *microwaves* for the purpose of locating, identifying, navigating, or guiding such moving objects as ships, aircraft, missiles, or artificial *satellites*. The system consists essentially of a generator of *electromagnetic radiation* of centimetric *wavelengths*, the output of which is *pulse modulated* (see *modulation*) at a *radio frequency* and fed to a movable *aerial* whence it is radiated as a *beam*. Distant objects that cross the path of the beam reflect the pulses back to the transmitter, which also acts as a receiver. A *cathode-ray tube* indicator displays the received signal in the correct time sequence so that the time taken for a pulse to travel to the object and back can be measured. Thus the distance of the object from the transmitter can be calculated, and its direction can be ascertained from a knowledge of the direction of the aerial. This fundamental technique has been extended so that automatic guidance and navigation can be effected by *computers* without the necessity of a display.

radial velocity See *line of sight velocity*.

radian The supplementary *SI unit* of plane *angle* defined as the angle subtended at the centre of a *circle* by an arc equal in length to the radius of the circle. 2π radians = 360° , 1 radian = 57.296° . Symbol rad.

radiant energy Energy that is transmitted in the form of *radiation*, particularly *electromagnetic radiation*. Radiant energy is the only form in which energy can exist in the absence of *matter*.

radiant flux Radiant power. The total power emitted or received by a body in the form of *radiation* (usually *electromagnetic radiation*). It is measured in *watts*.

radiant heat See *infrared radiation*.

radiation In general, the emission of any *rays*, *wave motion*, or particles (e.g. *alpha particles*, *beta particles*, *neutrons*) from a

source; it is usually applied to the emission of *electromagnetic radiation*.

radiation belts See *Van Allen radiation belts*.

radiation hazard The potential danger to health resulting from exposure to *ionizing radiation* or the consumption of *radioactive substances*.

radiation potential Resonance potential. The *energy* (expressed in *electron-volts*) necessary to transfer an *electron* from its normal position in an *atom* to some other possible position; i.e. to an *energy level* of greater energy.

radiation sickness Illness caused by exposure to *ionizing radiation*. Initial symptoms are vomiting and diarrhoea, followed in some cases by leukaemia.

radiative capture See *capture*.

radiative collision A collision between charged particles in which part of the *kinetic energy* is converted into *electromagnetic radiation*.

radical Radicle. 1. (chem.). A group of *atoms*, present in a series of *compounds*, that maintains its identity through chemical changes affecting the rest of the *molecule*, but that is usually incapable of independent existence. E.g. the *ammonium radical*, NH_4- ; *ethyl group*, C_2H_5- . See also *free radical*. 2. (math.). Relating to a *root*. The symbol $\sqrt{\quad}$ is called the 'radical sign'.

radio The use of *electromagnetic radiation* to communicate electrical signals without wires ('wireless' transmission). In the widest sense the term incorporates sound broadcasting (including *radio telephony* and *radio telegraphy*), *television*, and *radar*. Transmission by radio involves a transmitter feeding a transmitting *aerial*, from which *electromagnetic energy* is broadcast, either as *ground waves* or *sky waves*, to a receiving aerial, which feeds a receiver. The transmitter in sound broadcasting consists of a generator of a *radio frequency carrier wave* modulated (see *modulation*) in accordance with the *electric currents* provided by the amplified output of a *microphone*. The modulated carrier wave is fed to the transmitting aerial and if the receiving aerial is tuned to the *frequency* of the carrier wave (see *resonant circuit*) it will enable the receiver selectively to amplify and demodulate the transmitted signal. *Demodulation* is achieved by *rectification* of the signal by a *thermionic valve* or *transistor*. In this way a current is produced in the output stage of the receiver, which varies in *amplitude* in accordance with the frequency of the sound wave fed to the microphone at the transmitter. This current may then be used to operate a loudspeaker, which reproduces the original sound.

radio- See *radioactive*.

radioactive Possessing, or pertaining to, *radioactivity*. Sometimes only the prefix 'radio-' is used to describe radioactive *nuclides* or the substances containing them, e.g. radiocarbon is an abbreviation for radioactive carbon.

RADIOACTIVE AGE

radioactive age The age of a *mineral*, *fossil*, or wooden object as estimated from its content of *radioisotopes*. This method assumes that the content of *radioisotopes* has remained unchanged except for radioactive decay. See also *dating*; *potassium-argon dating*; *rubidium-strontium dating*; *radiocarbon dating*.

radioactive equilibrium A state ultimately reached when a *radioactive* substance of slow *decay* (see *radioactivity*) yields a radioactive product on *disintegration*. This product may also decay to give a further radioactive substance, and so on. The amount of any of the daughter radioactive products present after equilibrium has been reached remains constant, the loss due to decay being counterbalanced by gain from the decay of the immediate parent.

radioactive series Radioactive family. A series of *radioisotopes*, each except the first being the *decay* product of the previous one. The final member of the series, usually an isotope of lead, is stable. See *radioactivity*.

radioactive standard A specimen of a material containing a *radioisotope* of precisely known rate of *decay* that is used for the calibration of instruments measuring *radiation*.

radioactive tracing A method of tracing the course of an element through a biological, chemical, or mechanical system. Any two *isotopes* of an *element* are chemically identical. Thus, by introducing a small amount of a *radioisotope*, called a tracer, the course taken by the stable isotope of the same element can be followed or traced by detecting the course of the accompanying *radioisotope* by suitable means. This can be done in various ways; e.g. *Geiger counter*. See *labelled compound*.

radioactivity The property of spontaneous *disintegration* possessed by certain unstable types of atomic *nuclei*. The disintegration is accompanied by the emission of either *alpha-* or *beta-particles* and/or *gamma rays*. The most common type of disintegration involves beta-particle emission (see *beta decay*) and occurs either: (1) when a *neutron* present in the unstable nucleus is converted into a *proton* with the emission of an *electron* and an anti-*neutrino*, or more rarely (2) when a *proton* is converted into a *neutron* with the emission of a *positron* and a *neutrino*. These *beta transformations* are accompanied by unit change of *atomic number* but no change in *mass number*. Alpha particles are only emitted by certain *radioisotopes* of the heavier *elements* (see *alpha decay*); when this occurs the atomic number of the daughter nucleus is two less than that of the parent and its mass number is reduced by four units. Gamma-ray emission accompanies alpha or beta emission when the daughter nucleus is formed in an excited state (see *excitation*).

Natural radioactivity is due to the disintegration of naturally occurring *radioisotopes*, which may be arranged in three *radioactive series*. The rate at which *radioisotopes* disintegrate is uninfluenced

by any chemical changes, any normal changes of *temperature* or *pressure*, or by the effects of *electric* or *magnetic fields*. However 'induced' or 'artificial' *radioisotopes* of most elements can be formed by bombardment with particles (e.g. neutrons) or *photons* in a *nuclear reactor* or *accelerator*.

Radiations emitted by *radioisotopes* are used in the treatment of disease (see *radiotherapy*) and in *radioactive tracing*.

radio astronomy The study of heavenly bodies by the reception and analysis of the *radio frequency electromagnetic radiation* that they emit or reflect. In general, electromagnetic radiations from extraterrestrial sources are either absorbed by the Earth's *atmosphere* or reflected away from the Earth by the *ionosphere*. The two exceptions, which allow us to experience the rest of the *Universe*, are the optical *wavelengths*, which are able to penetrate the atmosphere, and the radio wavelengths in the band 1 cm-10 metres, which are too long to be absorbed by the atmosphere and too short to be reflected by the ionosphere. The radiations that pass through this 'radio window' onto the Universe come from a variety of sources, ranging from objects within the *solar system* (e.g. the *Sun* and the *planet Jupiter*) to *galaxies* that are too distant to be observed by *optical telescopes*. Radio frequency emission may be due to thermal or non-thermal causes: emission from the *quiet Sun* is of thermal origin for example, whereas the radiation from *sunspots* is of unexplained non-thermal origin. The method by which radio astronomy attempts to make sense out of the apparently incoherent radio 'noise' from the Universe, is to construct maps of the sky in terms of radio emission, at several different *frequencies*. The intensities of the sources thus located are then compared with optical observations. In this way *radio sources* and *radio galaxies* have been identified. See also *radio telescope*.

radiobiology The branch of *biology* concerned with the effects of *radiation* on living *organisms* and the behaviour of *radioactive* materials, or the use of *radioactive tracing*, in biological systems.

radiocarbon dating The estimation of the age of wooden archaeological objects by measuring their content of the *radioisotope* of carbon, ^{14}C . The impact of *cosmic rays* on the Earth's *atmosphere* causes a very small proportion of nitrogen atoms to transform into ^{14}C atoms. Some of these radioactive carbon atoms find their way, via *carbon dioxide* and *photosynthesis*, into living trees. When a tree is cut down, however, it ceases to acquire further ^{14}C atoms. Therefore by comparing the *radioactivity* of a modern piece of wood with that of a specimen of unknown age, the length of time that has elapsed since the latter ceased to be living can be estimated (provided that it is not more than about 6000 years). This method has been checked by comparison with specimens of wood of known

RADIOCHEMISTRY

age from the tombs of the Pharaohs and has been found to be fairly reliable.

radiochemistry The study and application of chemical techniques to the purification of *radioactive* materials and the formation of *compounds* containing *radioactive elements*.

radiodiagnosis The branch of medical *radiology* concerned with the application of *X-rays* to diagnosis.

radiofrequency The *frequency* of *electromagnetic radiation* within the range used in *radio*, i.e. 10 kilohertz to 100 000 megahertz.

radiofrequency heating Industrial *induction* or *dielectric heating*, particularly when the *frequency* of the alternating field is above about 25 kilohertz.

radiofrequency welding See *high frequency welding*.

radio galaxies *Galaxies* that emit *electromagnetic radiation* of *radiofrequencies* as observed by the techniques of *radio astronomy*. The exact source of this galactic radiation is not always understood, but radiation has been received from galaxies that have been observed optically to be in collision. See also *radio sources*, *quasars*, *pulsars*, and *synchrotron radiation*.

radiogenic Resulting from *radioactive decay*.

radiograph A photographic record of an image produced by short *wavelength radiation*, such as *X-rays* and *gamma rays*.

radiography The formation of images on *fluorescent* screens or photographic material by short *wavelength radiation*, such as *X-rays* and *gamma rays*.

radio interferometer A type of *radio telescope* that consists of two or more separate *aerials*, each receiving *electromagnetic radiation* of *radiofrequencies* from the same source, and each joined to the same receiver. The instrument works on the same principle as the optical *interferometer*, but as the *wavelengths* of the incident radiation are much greater, the distance between aerials has to be correspondingly increased. The chief advantage of radio interferometers, over single aerial *parabolic reflectors*, is that they can be made more sensitive to radiation from sources of small angular diameter. See also *radio astronomy*.

radioisotope An *isotope* of an *element* that is *radioactive*.

radilocation The location of distant objects, such as ships or aircraft, by *radar*.

radiology The science of *X-rays* and *radioactivity*, including *radio-diagnosis* and *radiotherapy*.

radiolucent Almost *transparent* to *radiation*, especially *X-rays* and *gamma rays*, but not entirely so. An object or material that allows these radiations to pass with little or no alteration is said to be 'radiotransparent'. Objects and materials that are *opaque* to them are said to be 'radioopaque'.

radioluminescence *Fluorescence* resulting from *radioactive decay*.

radiolysis The chemical *decomposition* of substances as a result of *irradiation*.

radiomicrometer An extremely sensitive instrument for measuring *heat radiations*. It consists of a *thermocouple* connected directly into a single copper loop forming the coil of a sensitive *galvanometer*.

radionuclide A *nuclide* of an *atom* that is *radioactive*.

radioopaque See *radiolucent*.

radiosonde A small balloon used to carry meteorological instruments into the *Earth's atmosphere*. Measurements of *temperature*, *pressure*, etc. are transmitted by these instruments back to Earth by *radio*.

radio source Formerly known as a 'radio star', a term which is no longer used. A discrete source of *electromagnetic radiation* of *radiofrequencies* outside the *solar system*. Such sources have been discovered by the techniques of *radio astronomy*, both within the *Galaxy* and outside it, but only a small number have been identified with *stars* that can be located with *optical telescopes*. Other sources are *supernovae* explosions and remnants, colliding *galaxies* and gas clouds, *quasars*, and *pulsars*; some sources, however, remain unexplained.

radio star See *radio source*.

radio telegraphy The transmission of coded messages (e.g. in Morse code) by *radio*.

radio telephony The use of *radio*, rather than wires or cables, for all or part of a *telephone system*.

radio telescope An instrument used in *radio astronomy* to pick up and analyse the *radiofrequency electromagnetic radiations* of extra-terrestrial sources. The two principal types of radio telescope are: (1) *parabolic reflectors*, which are usually steerable so that they can be pointed at any part of the sky, and which reflect the incoming radiation on to a small *aerial* at the *focus* of the *paraboloid*; and (2) *fixed radio interferometers*. The latter have greater position-finding accuracy and greater ability to distinguish a small source against an intense background, while the former are more versatile owing to their mobility.

radiotherapy The treatment of disease by means of *radiation*, particularly *X-rays* and techniques involving *radioactivity*.

radiotransparent See *radiolucent*.

radio window See *radio astronomy*.

radium Ra. Naturally occurring *radioactive element*. At. No. 88. The most stable *isotope*, $^{226}_{88}\text{Ra}$, has a *half-life* of 1620 years. A very rare *metal*, chemically resembling barium; m.p. 700°C., r.d. 5. See *radioactivity*.

radium emanation See *radon*.

RADIUS

radius See *circle*.

radius of curvature Consider any point P on a curve S lying in a *plane*.

A *circle* can be drawn with centre at a unique point O on the *normal* to S at P , such that the curve and the circle are tangential at P . The radius of this circle, OP , is the radius of curvature of the curve at P . The concept may be extended to a point on a three-dimensional curved surface. In this case, an infinite number of radii of curvature exist, corresponding to the infinite number of plane curves that can form the line of intersection of the curved surface and the plane containing the normal at P . Of these curves, two are unique, one having a maximum radius of curvature at P and the other a minimum. These two are called the principal radii of curvature at P .

radius of gyration The *moment of inertia* I , of a body of mass m about a given *axis* can be expressed in the form $I = mk^2$, k being the radius of gyration about the axis.

radius vector (astr.) A line drawn from a central body (the focus) to a *planet* in any position in its *orbit*.

radius vector (math.) The position of any point P in space with respect to a given *origin* O may be completely defined by the direction and length of the line OP . This line is called the radius vector of the point P . See *polar coordinates*.

radix A number that forms the *base* of a system of numbers, *logarithms*, etc., e.g. the radix of the *binary notation* is 2.

radon Rn. Radium emanation, niton. Element. At. No. 86. The most stable *isotope*, $^{222}_{86}\text{Rn}$, has a *half-life* of 3.825 days. A naturally occurring *radioactive* gas, produced as the immediate *decay* product of radium. Chemically it is a member of the *inert gases*.

raffinate A *refined liquid*, especially an oil after its *soluble* components have been removed by *solvent extraction*.

raffinose Melitose. $\text{C}_{18}\text{H}_{32}\text{O}_{16} \cdot 5\text{H}_2\text{O}$. A colourless crystalline *trisaccharide*, m.p. 80°C ., that occurs in *beet sugar* but does not have a sweet flavour.

rainbow A colour effect produced by the *refraction* and internal *reflection* of sunlight in minute droplets of *water* in the air; the effect is visible only when the observer has his back to the *Sun*.

Raman effect When *monochromatic light* passes through a *transparent* medium, some of the light is scattered. If the *spectrum* of this scattered light is examined, it is found to contain, apart from light of the original *wavelength*, weaker lines differing from this by constant amounts. Such lines are called Raman lines, and they are due to the loss or gain of *energy* experienced by the *photons* of light as a result of interaction with the vibrating *molecules* of the medium through which they pass. The Raman effect is therefore useful in the study of molecular *energy levels*. Named after Sir C. V. Raman.

ram jet *Atherodyde, athodyd.* A simple type of aerodynamic *reaction propulsion* system in which *thrust* is obtained by the *combustion* of *fuel* in air, compressed only by the forward *velocity* of the vehicle. A ram jet is also known as a 'flying drainpipe' as it consists essentially of a long duct into which fuel is fed at a controlled rate. However, the air intake and exhaust gas outlet need to be correctly designed in order to achieve maximum efficiency of the combustion process in that part of the duct that serves as a combustion chamber. The shape of the duct will depend upon whether or not the velocity of the vehicle is intended to be *supersonic*. A ram jet has to be launched at high velocity and cannot take off unaided from rest. See also *pulse-jet*.

Ramsden eye-piece An eye-piece consisting of two *plano-convex lenses* (curved surfaces inwards) of equal *focal length* f , and separated by a distance of $2f/3$. The eye-piece has low spherical *aberration*, is fairly *achromatic* and is very useful when cross-wires or a scale are desired in the eye-piece. Named after Jesse Ramsden (1735-1820).

random sample A sample taken in such a way that every individual, object, or component comprising the group, set, or mass to be sampled, has an equal *probability* of forming part of the sample.

Raney nickel A spongy type of nickel, used as a *catalyst*, especially in the *hydrogenation* of fats and oils. It is made by dissolving the aluminium in a nickel-aluminium alloy with *sodium hydroxide*.

Rankine temperature °R. The absolute *Fahrenheit scale*. Zero degrees Rankine is -459.67°F . and therefore $^{\circ}\text{F} + 459.67 = ^{\circ}\text{R}$. Named after W. J. M. Rankine (1820-70).

Raoult's law When a *solute* that does not dissociate (see *ionic hypothesis*) in *solution* is dissolved in a *solvent* to form a *dilute* solution, then (1) the ratio of the decrease in *vapour pressure* to the original vapour pressure is equal to N_1/N_2 , N_1 and N_2 being the total numbers of *molecules* present of solute and solvent respectively; or, alternatively (2) the *elevation of the boiling point* of the solution above that of the pure solvent is proportional to N_1/N_2 ; or (3) the *depression of the freezing point* of the solution below that of the pure solvent is proportional to N_1/N_2 . Named after Francois Raoult (1830-1901).

rapeseed oil See *colza oil*.

rare earth elements See *lanthanides*.

rarefaction A reduction in *pressure*. The opposite of *compression*.

rare gases See *inert gases*.

raster The pattern of lines that scan the fluorescent screen of a *cathode ray tube* in a *television* receiver.

ratio The numerical relation one quantity bears to another of the same kind. E.g. 6 tons and 4 tons, and 30 and 20, are both in the ratio of 3:2.

RATIONAL NUMBER

rational number (math.) A whole number, or a number that can be expressed as the *ratio* of two whole numbers.

ray The *rectilinear* path along which any *radiation*, e.g. *light*, travels in any direction from a point in the source of the radiation. Loosely used to denote radiation of any kind.

rayon Formerly 'artificial silk', the term is now restricted to two types of man-made *cellulose* fibres: (1) *viscose rayon*, made by forcing a solution of viscose through fine holes into a *solution* that decomposes the viscose to give threads of cellulose, and (2) *cellulose acetate rayon*, made by forcing a solution of cellulose acetate through fine holes into warm air and allowing the *solvent* to *evaporate*, thus leaving threads of cellulose acetate.

RDX* See *cyclonite*.

reactance *X*. A property of *alternating current* circuits that together with the *resistance*, *R*, makes up the *impedance* *Z*, according to the relation, $Z = (R^2 + X^2)^{\frac{1}{2}}$. If the circuit comprises the resistance, an *inductance* *L*, and *capacitance* *C* all in series, the reactance is given by:

$$X = \omega L - 1/\omega C$$

where ω is the angular frequency ($\omega = 2\pi f$, *f* being the *frequency* of the *alternating current*).

reactant A substance that takes part in a *chemical reaction*.

reaction, chemical See *chemical reaction*.

reaction propulsion Jet propulsion. A form of aerodynamic propulsion in which a high *velocity* stream of *gas* (usually produced by *combustion*) reacts upon the vehicle in which it was produced in accordance with *Newton's* (third) *law of motion*, so that the vehicle is propelled through the medium in which it is travelling. The lower the *density* of the medium, the higher the *efficiency* of the propulsion. Reaction propulsion is the only known method of propulsion through *space* where there is no supporting medium, and it is upon this principle that *rockets* are propelled. See also *jet engine*, *ion engine*.

reactive (chem.) Readily entering into *chemical reactions*; chemically active.

reactive dyes *Dyes* that react chemically with the substances being dyed, to form chemical compounds.

reactor (chem.) Any vessel in which a *chemical reaction* (especially industrial) is conducted.

reactor (phys.) 1. A device for introducing reactance into an electrical circuit (e.g. a *capacitor*). 2. See *nuclear reactor*.

reagent A chemical substance used to produce a *chemical reaction*.

realgar Natural red *arsenic disulphide*, As_2S_2 .

real image See *image*, *real*.

real-time working A method of operating a *computer* as part of a larger system, in which information from the computer output is available at the time it is required by the rest of the system.

Réaumur scale A *temperature* scale in which the *melting point* of ice is taken as 0°R. and the *boiling point* of water as 80°R. Named after Rene Antoine Réaumur (1683-1757).

reciprocal of a quantity 1 divided by the quantity; e.g. the reciprocal of 5 is 1/5.

reciprocal ohm See *mho* and *siemens*.

reciprocal proportions, law of See *chemical combination, laws of*.

recoil electron See *Compton effect*.

rectangle A *quadrilateral* with right angles between all four sides.

rectification (chem.) The purification of a *liquid* by *distillation*.

rectification (math.) The process of determining the length of a curve.

rectification (phys.) The conversion of an *alternating* into a *direct current*. See *rectifier*.

rectified spirit *Ethanol*, usually obtained by *fermentation* on an industrial scale, and purified by *fractional distillation*.

rectifier (phys.) A device for transforming an *alternating current* into a *direct current*; it consists of an arrangement that presents a much higher *resistance* to an *electric current* flowing in one direction than in the other. See *rectifying valve*; *crystal rectifier*; *barrier-layer rectifier*; *junction rectifier*; *semiconductor*.

rectifying valve The *thermionic valve* commonly used for *rectification* is the *diode*. The valve will pass current only when the *anode* is at a positive *potential* with respect to the *cathode*. Hence if an *alternating potential* is applied to a circuit containing such a valve, a *direct current* will flow through the circuit. For most purposes *rectifying valves* have now been replaced by *semiconductor diodes*.

rectilinear In a straight line; consisting of straight lines.

rectilinear propagation of light To a first approximation *light* travels in straight lines, as is evident from the formation of *shadows* and other everyday experience; see, however, *diffraction*.

red giant A type of *star*; see *stellar evolution*.

red lead *Minium*. Pb_3O_4 . A bright scarlet powder, used as a *pigment*, in *glass* manufacture, and as an *oxidizing agent*.

redox exchanger *Electron exchanger*. A substance, usually a polymer, that can "exchange" (i.e. transfer) *electrons*, thereby effecting *redox reactions*, when in contact with reacting *ions* or *molecules*. Redox exchangers may also act as *ion exchangers*. See *ion exchange*.

redox reaction. *Oxidation-reduction reaction*. A *chemical reaction* in which an *oxidizing agent* is reduced and a *reducing agent* is oxidized, thus involving the transfer of *electrons* from one *atom*, *ion*, or *molecule* to another. The 'redox potential', is the *potential* required in a *cell* to produce *oxidation* at the *anode* and *reduction*

RED SHIFT

at the *cathode*. This potential is measured relative to a standard *hydrogen electrode*, which is taken as zero.

red shift See *Doppler effect*.

reduced equation An *equation of state* of a gas in which the temperature, pressure, and volume are replaced by their reduced values. See *reduced temperature, pressure, and volume*.

reduced temperature, pressure, and volume Ratios of the *temperature*, the *pressure*, and the *volume* to the *critical temperature*, *critical pressure*, and *critical volume* respectively.

reducing agent A substance that removes oxygen from, or adds hydrogen to, another substance: in the more general sense, one that donates *electrons*. See *reduction*.

reductase An *enzyme* that promotes a *reduction* reaction.

reduction The removal of oxygen from a substance, or the addition of hydrogen to it. The term is also used more generally to include any reaction in which an *atom* gains *electrons*.

redundancy A term used in *information theory*: the amount by which the *ratio* of the information rate to its hypothetical maximum value falls below unity; usually expressed as a percentage.

re-entry The position, time, or act of re-entering the *Earth's* atmosphere after a journey into *space*. The 'angle of re-entry' is critical because of the enormous quantity of *heat* generated by a *spacecraft* as it enters the atmosphere. This heat is generated by *friction* between the *atoms* and *molecules* of the atmosphere and the great speed of the moving spacecraft; it is normally absorbed by the *heat shield*. Too sharp an angle of re-entry would cause the spacecraft to burn up, too oblique an angle would cause the spacecraft to bounce off the atmosphere.

refine Purify: remove the impurities from (*sugar, metals, oil, etc.*).

reflectance A measure of the extent to which a surface is capable of reflecting *radiation*, defined as the *ratio* of the intensity of the reflected radiation to the intensity of the incident radiation.

reflecting telescope Reflector. See *telescope*.

reflection, angle of The angle between a *ray of light* reflected from a surface, and the *normal* to the surface at that point.

reflection, total internal See *total internal reflection*.

reflection of light Certain surfaces have the property of reflecting or returning *rays of light* that fall upon them, according to definite laws (see *reflectance; reflection of light, laws of*).

reflection of light, laws of 1. The incident *ray*, the reflected *ray*, and the *normal* to the reflecting surface at the point of incidence lie in the same *plane*. 2. The *angle* between the incident *ray* and the *normal* (i.e. the angle of *incidence*) is equal to the angle between the reflected *ray* and the *normal* (i.e. the angle of *reflection*).

reflector 1. Any surface that reflects *radiation*, particularly *electromagnetic radiation* (See also *parabolic reflector*). 2. A reflecting

telescope. See *telescope*. 3. A layer of material (which may contain a *moderator*) surrounding the core of a *nuclear reactor* that reflects back into the core some of the *neutrons* that would otherwise escape.

reflex angle An angle greater than 180° and less than 360° .

reflex camera A camera that allows the photographer to view the exact scene he is photographing. It incorporates a movable plane *mirror* to reflect the scene viewed by the camera *lens* on to a groundglass screen. Some reflex cameras use a similar principle but have a separate lens for viewfinding.

reflux condenser A *condenser* in which the *vapour* over a *boiling liquid* is condensed to a liquid, which flows back into the vessel, so preventing its contents from boiling dry.

refracting telescope Refractor. See *telescope*.

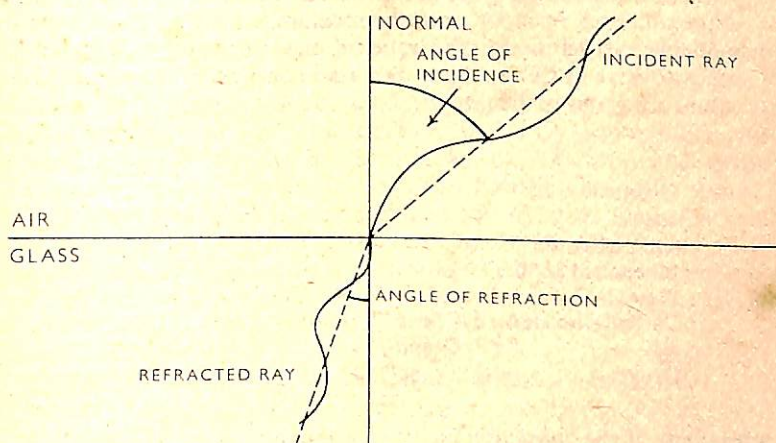


Figure 35.

refraction, angle of The angle between the refracted ray and the *normal* to the surface at the point of *refraction*. See Fig. 35.

refraction, laws of 1. The incident ray, the refracted ray, and the *normal* to the surface of separation of the two media at the point of incidence lie in the same *plane*. 2. Snell's law. The ratio of the sine of the *angle of incidence* to the sine of the *angle of refraction* is a constant for any pair of media. See *refractive index*. Named after Willebrord Snell (1591-1626).

refraction correction The small correction that has to be made to the observed *altitude* of a heavenly body due to the *refraction* of the *light* it emits or reflects by the Earth's *atmosphere*. All bodies appear to be slightly higher than they actually are.

REFRACTION OF LIGHT

refraction of light When a ray of *light* travels obliquely from one medium to another, it is bent or refracted at the surface separating the two media. The refraction occurs because light travels at slightly different *velocities* in different media; thus at the interface between media there is a slight change of *wavelength*. See Fig. 35. The ray before refraction is called the incident ray; on being refracted it becomes the refracted ray. A line perpendicular to the refracting medium at the point where the incident ray enters it is the *normal*. *Glass*, *water*, etc., cause the incident ray to be turned towards the normal when the ray enters from a medium less optically dense, such as air. Similar considerations apply to wave motions other than light.

refractive index of a medium n The ratio of the sine (see *trigonometrical ratios*) of the angle of *incidence* to the sine of the angle of *refraction* when *light* is refracted from a *vacuum* (or, to a very close approximation, from air) into the medium. This is equivalent to the fundamental definition: the ratio of the *velocity* of *light* in free space to that in the medium. See *refraction of light*. Some typical values are given in the table.

	<i>Refractive indices</i>
Diamond	2.4173
Glass	1.5–1.7
Quartz (fused)	1.458
Ethanol (at 25°C.)	1.359
Water (at 25°C.)	1.332
Carbon Dioxide (at 0°C. and 760 mm)	1.000450
Air (at 0°C. and 760 mm)	1.000293
Oxygen (at 0°C. and 760 mm)	1.000272

refractivity If the *refractive index* of a medium is n , its refractivity is defined as $n-1$. The 'specific refractivity' is given by $(n-1)/\rho$ where ρ is the *density* of the medium; the 'molecular refractivity' is defined as the specific refractivity multiplied by the *molecular weight*.

refractometer An apparatus for the measurement of the *refractive index* of a substance.

refractor 1. Any surface that refracts *radiation*. 2. A refracting telescope. See *telescope*.

refractory (chem.) A material not damaged by heating to high *temperatures*. Such materials are made into bricks and used for lining furnaces, etc.

refrigerant A *fluid* used in the *refrigerating cycle* of a refrigerator, usually consisting of a *liquid* that will vaporize at a low *temperature* (e.g. *freon* or *ammonia*).

refrigerating cycle The cycle of operations that takes place in a refrigerator. The *refrigerant* absorbs *heat* from the cold chamber

and its contents, which causes it to vaporize; it is then pumped to a compressor where it gives up heat and condenses back to a *liquid*; it again passes to the cold chamber, thus constituting a continuous cycle.

regelation of ice The *melting point* of *ice* is lowered by increased *pressure*; therefore ice near its melting point is melted by sufficient pressure, and solidification or regelation takes place again when the pressure is removed.

regenerator A *heat exchanger* usually consisting of a chamber filled with bricks arranged in checkerwork. The exhaust gases from a furnace, and the cold air to be used in the *combustion*, are passed alternately through the chamber for specified periods. *Heat* from the exhaust gases is stored in the brickwork and transferred to the cold air, thus increasing the efficiency of the combustion process.

relative aperture See *f-number*.

relative atomic mass See *atomic weight*.

relative density (r.d.) Specific gravity. The ratio of the density of a solid or liquid at a specified temperature (often 20°C.) to the density of water at the temperature of its maximum density (4°C.). It is a pure number, but is numerically equal to the density in grams per cubic centimetre. The density in *SI units* (kg m^{-3}) is 1000 times greater than the relative density. If the r.d. of a substance is less than 1 it will float on water, if it is greater than 1 it will sink. The r.d. of gases is usually expressed with reference to air, both gases being at *S.T.P.* The table gives the relative densities of some common materials. The term has now replaced the older term, *specific gravity* (see *specific*).

THE RELATIVE DENSITY OF SOME COMMON MATERIALS

<i>Material</i>	<i>r.d.</i>	<i>Material</i>	<i>r.d.</i>
Cork	0.24	Aluminium	2.7
Pine	0.45	Diamond	3.5
Oak	0.80	Titanium	4.5
Water	1.00	Iron (cast)	6.9–7.5
Brick	1.6	Steel	7.6–7.8
Earth	1.9–2.1	Brass (cast)	8.1
Cement (set)	2.2	Lead	11.3
Granite	2.6	Mercury	13.6
Marble	2.7	Gold	19.3

relative humidity The hygrometric state of the atmosphere can be defined either as: (1) the ratio of the *pressure* of the *water vapour* actually present in the atmosphere to the pressure of the vapour that would be present if the vapour were *saturated* at the same

RELATIVE MOLECULAR MASS

temperature; or (2) the ratio of the *mass* of water vapour per unit volume of the air to the mass of water vapour per unit volume of saturated air at the same temperature. The numerical difference between the two is very small and can normally be neglected. The relative humidity is usually expressed as a percentage. Its value may be determined from a knowledge of the *dew-point*, since the *saturated vapour pressure* at the dew-point is equal to the aqueous vapour pressure at the temperature of the experiment. The result is then obtained by reference to tables, which give the saturated vapour pressure at different temperatures.

relative molecular mass See *molecular weight*.

relative permeability See *magnetic permeability*.

relative permittivity See *permittivity*.

relativistic mass The *mass* of a body that is travelling at a speed comparable to the *velocity of light*. The relativistic mass, m , of a body travelling at a velocity, v , is given by:

$$m = m_0 \sqrt{1 - v^2/c^2}$$

where m_0 is the *rest mass* and c is the velocity of light.

relativistic particle A particle that has a speed comparable to the *velocity of light*; i.e. a particle with a *relativistic mass* substantially in excess of its *rest mass*.

relativistic velocity A *velocity*, approaching the *velocity of light*, at which the effect of the theory of *relativity* is significant.

relativity, theory of A theory, formulated by Einstein, that recognizes the impossibility of determining absolute motion and leads to the concept of a four-dimensional *space-time continuum*. The special theory, which is limited to the description of events as they appear to observers in a state of uniform motion relative to one another, is developed from two axioms: (1) the laws of natural phenomena are the same for all observers, and (2) the velocity of *light* is the same for all observers irrespective of their own *velocity*. The more important consequences of this theory are (a) the *mass* of a body is a function of its velocity (see *relativistic mass*); (b) the *mass-energy equation* for the interconversion of mass and energy; (c) the *Fitzgerald-Lorentz contraction* appears as a natural consequence of the theory; (d) time has no absolute value (see *time dilation*). The general theory, applicable to observers not in uniform relative motion, leads to a novel concept of the theory of *gravitation*. In this theory the presence of *matter* in *space* causes space to 'curve' in such a manner that the *gravitational field* is set up. Thus gravitation becomes a property of space itself. The validity of the theory of relativity has been amply confirmed in modern *physics*.

relay, electrical A device by which the *electric current* flowing in one circuit can open or close a second circuit and thus control the switching on and off of a current in the second circuit. Electrical

relays may be mechanical switches operated by *electromagnets*, or they may be *electronic* switches based upon mercury or gas-filled *thermionic valves* e.g. a *thyatron*, or on *semiconductor* devices.

reluctance The ratio of the *magnetomotive force* acting in a *magnetic circuit* to the *magnetic flux*.

reluctivity The *reciprocal* of *magnetic permeability*.

rem Roentgen equivalent man. The unit dose of *ionizing radiation* that gives the same biological effect as that due to one *roentgen* of *X-rays*.

remanence The residual magnetization of a *ferromagnetic substance* subjected to a *hysteresis cycle* when the magnetizing field is reduced to zero.

rennet An extract of the fourth stomach of the calf, containing *rennin*.

rennin An *enzyme* having the power of coagulating the *protein* in milk.

resins Natural resins are *amorphous organic compounds* secreted by certain plants and insects; they are usually *insoluble* in water but *soluble* in various *organic solvents*. Typical natural resins are *rosin* and *shellac*. *Synthetic* resins were originally described as a group of synthetic substances whose properties resembled natural resins. The term is now applied more generally to any synthetic *plastic* material produced by *polymerization*, although chemically modified natural *polymers*, such as those based on *cellulose* or *casein*, are not usually classed as synthetic resins.

resistance, electrical *R* The ratio of the *potential difference* between the ends of a conductor to the *electrical current* flowing in the conductor. See *Ohm's law*. All materials except *superconductors* resist the flow of an electric current, converting a proportion of the *electrical energy* into *heat*. The extent to which a conductor resists the flow of a given current depends upon its physical dimensions, the nature of the material of which it is made, its *temperature*, and in some cases the extent to which it is illuminated. See *photoconductive effect*. The derived *SI unit* of resistance is the *ohm*.

resistance thermometer The electrical *resistance* of a *conductor* varies with *temperature*, normally increasing with rise in temperature. This forms the basis of a convenient and accurate *thermometer*, in which the temperature is deduced from the measurement of the resistance of a spiral of a metal (usually platinum) in the form of a wire.

resistivity Specific resistance. A constant for any material equal to the *reciprocal* of its *conductivity*. The resistivity is defined as the *resistance* offered by a cube of the material at 0°C. Thus the resistivity, ρ equals RA/l where R is the resistance of a uniform conductor of length l and cross-sectional area A . It is usually expressed in *ohm metres*.

resistor A device used in *electronic* circuits primarily for its *resistance*.

RESOLUTION OF FORCES

The most common types are either 'wire-wound', or made of finely ground carbon particles mixed with a *ceramic* binder.

resolution of forces The division of *forces* into components that act in specified directions.

resolving power The ability of an optical system (e.g. *microscope*, *telescope*, the eye, etc.) to produce separate images of objects very close together.

resonance (chem.) Quantum-chemical resonance, mesomerism. The description of the structure of a molecule in terms of definite *valence* states of its atoms, and integral numbers of *valence bonds* between the atoms, gives an over-simplified picture of the actual state of the molecule, whose characteristics, e.g. *electron-density* distribution, may be inconsistent with any classical formula. The resonance or valence-bond method of describing approximately the actual structure of a compound uses a number of classical structures ("resonance forms"), in terms of which the actual structure (the "resonance hybrid") is described. See *benzene ring*.

resonance (phys.) If, to a system capable of oscillation, a small periodic *force* is applied, the system is in general set into forced oscillations of small *amplitude*. As the *frequency*, f , of the exciting force approaches the *natural frequency* of the system, f_0 , the amplitude of the oscillations builds up, becoming a maximum when $f = f_0$. The system is then said to be in resonance with the exciting force, or simply in resonance.

resonance, nuclear Resonance is said to occur in *nuclear reactions* if the *energy* of an incident particle or *photon* is equal, or near, to the value of an appropriate *energy level* of the compound *nucleus*. Thus a resonance *neutron* is one whose energy corresponds to a particular energy level of a nucleus that will readily absorb it.

resonance neutron See *resonance, nuclear*.

resonant cavity A space enclosed by electrically conducting surfaces, in which electromagnetic *energy* may be stored or excited. The *frequency* of the oscillations within a resonant cavity will depend upon its physical dimensions.

resonant circuit An *electronic* circuit, containing both an *inductance* and a *capacitance*, that is capable of *resonance*. When the *capacitor* discharges through the inductor an induced *E.M.F.* is produced, which charges the capacitor again in the opposite sense; this again discharges through the inductor and the circuit will continue to oscillate in this way provided that it is supplied with *energy* from an external source. The *frequency* of the oscillation will depend upon the values of the capacitance and the inductance, and the circuit can therefore be tuned to resonate at any desired frequency by suitable alteration of the value of its components. Coupled with a *thermionic valve* or *transistor* to supply energy, a resonant circuit is used in

radio transmitters to generate *radio frequency* oscillations, and in receivers for their selective detection.

resorcinol *m*-Hydroxybenzene. 1,3-Benzenediol. $C_6H_4(OH)_2$. A solid *dihydric phenol*, m.p. $110^{\circ}C$. Used in tanning and as an *intermediate* in the manufacture of *resins*, *drugs*, and other products.

respiration *Aerobic* respiration is the process by which living *organisms*, or their components, take oxygen from the *atmosphere* to oxidize their food to obtain *energy*. *Anaerobic* respiration is the process by which organisms or their components, obtain *energy* from chemically combined oxygen when they do not have access to free oxygen. Many organisms can respire anaerobically for a short time only, but certain *bacteria* depend entirely on anaerobic respiration.

respiratory pigment A substance formed in *blood cells* or *blood plasma* that is capable of combining loosely and reversibly with oxygen, e.g. *haemoglobin*.

respiratory quotient RQ. The ratio of the *volume* of *carbon dioxide* expired by an *organism* or tissue to the volume of oxygen consumed by it over the same period.

restitution, coefficient of *e*. A measure of the *elasticity* of bodies upon impact. For two smooth spheres of a given material colliding, *e* is equal to the ratio of the relative *velocity* of the spheres along their line of centres immediately after impact to their relative velocity before impact.

rest mass The *mass* of a body when at rest relative to the observer. The mass of a body varies with its *velocity* (see *relativity, theory of*), a result of great importance when velocities approaching those of *light* are considered, e.g. in *nuclear physics*. See *relativistic mass*.

resultant (phys.) A single *force* or *velocity* that produces the same effect as the two or more forces or velocities acting together.

retardation (phys.) Deceleration. Negative *acceleration*; the rate of decrease of *velocity*.

retort (chem.) 1. A glass vessel consisting of a large bulb with a long neck narrowing somewhat towards the end. 2. In industrial processes, any vessel in which a *chemical reaction* or process takes place, especially *distillation*. 3. In the canning industry, a large *autoclave* for heating sealed cans by *superheated steam* under pressure.

retort carbon See *gas carbon*.

retrograde motion See *direct motion*.

retro-rocket A small *rocket*, forming part of a larger one, that produces *thrust* in the opposite direction to that of the main rocket with the object of decelerating it; e.g. to enable a lunar *module* to make a 'soft' landing on the *Moon*.

reverberatory furnace A furnace designed for operations in which it is not desirable to mix the material with the *fuel*; the roof is heated by *flames*, and the *heat* is radiated down on to the material off the roof.

REVERSIBLE PROCESS

reversible process (in *thermodynamics*) A hypothetical process that can be performed in the reverse direction, the whole series of changes constituting the process being exactly reversed. A reversible process can take place only in infinitesimal steps about equilibrium states of the system. In practice, all real processes are irreversible.

reversible reaction A *chemical reaction* that may be made, under suitable conditions, to proceed in either direction. See *chemical equilibrium*.

Reynolds number (*Re*) A dimensionless quantity applied to a *liquid* flowing through a cylindrical tube, given by $(Re) = u\rho l/\eta$, where u = *velocity* of flow, ρ = *density* of the liquid, l = the diameter of the tube, and η = the coefficient of *viscosity* of the liquid. At low velocities, the flow of the liquid is *streamline*. At a certain value of (*Re*), corresponding to a critical velocity u_c , the flow becomes *turbulent*. Named after Osborne Reynolds (1842-1912).

rhe The unit of *fluidity*. The *reciprocal* of the *poise*.

rhenum Re. Element. A.W. 186.20. At. No. 75. A hard heavy grey metal, r.d. 20.53, m.p. 3167°C. Used in *thermocouples* and as a catalyst.

rheology The study of the deformation and flow of *matter*.

rhopexy The acceleration of a thixotropic (see *thixotropy*) increase of *viscosity* by gentle stirring.

rheostan An alloy of 52% copper, 25% nickel, 18% zinc, and 5% iron that is used for electrical resistance wire.

rheostat A variable electrical resistor.

rhesus factor Rh factor. A group of *antigens* in the red blood cells of some humans (said to be Rh positive) but absent in some individuals (Rh negative). If a Rh negative mother conceives a Rh positive foetus, a severe reaction may in some circumstances occur. The chief danger is to second and subsequent children born to a Rh negative mother.

rhodium Rh. Element. A.W. 102.905. At. No. 45. A silvery-white hard metal, r.d. 12.5, m.p. 1966°C. It occurs with and resembles platinum. Used in *alloys*, *catalysts*, and *thermocouples*.

rhodopsin Visual purple. A complex *organic compound* formed in the retina of the eye. It makes the eye more sensitive in very dim light; lack of it causes night blindness. It is formed with the aid of *vitamin A*.

rhombus A *quadrilateral* having all its sides equal.

r_H scale A scale of hydrogen pressures that gives a measure of the strength of a *reducing agent*. The r_H value is defined as $\log_{10} 1/[H]$, where $[H]$ is the hydrogen pressure that would produce the same electrode potential as that of a given *redox reaction* at the same *pH* value.

riboflavin Lactoflavin. Vitamin B₂. C₁₇H₂₀N₄O₆. A water soluble substance, which is a member of the *vitamin B* complex. It forms part of various *enzymes* concerned with cellular *respiration*,

promotes growth in the young, and plays an important part in the health of the skin. Also known as vitamin G.

ribonuclease An enzyme that catalyzes the hydrolysis of ribonucleic acid.

ribonucleic acid RNA. Long thread-like molecules consisting of single polynucleotide chains. The sugar of the nucleotides is ribose, and the four nitrogenous bases that occur in them are the same as those found in deoxyribonucleic acid, except that uracil replaces thymine. RNA is the chief constituent, together with protein, of many types of virus, and it appears to be responsible for the self-replication of the virus. 'Messenger' RNA transmits the coded information contained by the chromosomes of the nucleus of a cell to the protein-making ribosomes of the cytoplasm. 'Transfer', soluble or t-RNA transfers the activated amino acids on to the messenger RNA.

ribose $C_5H_{10}O_5$. A pentose, m.p. $95^\circ C$.; the dextrorotatory form is of great biological importance as it occurs in the nucleotides of ribonucleic acid.

ribosomes Small granules (about 10^{-8} metre in diameter) that occur in the cytoplasm of cells and appear to be the sites of protein synthesis.

ricinoleic acid $C_{17}H_{32}OHCOOH$. A yellow liquid, b.p. $227^\circ C$., that occurs in castor oil and is used in the manufacture of soap.

rigidity modulus Elastic modulus applied to a body under a shearing strain.

ring compound (chem.) A chemical compound in the molecule of which some or all of the atoms are linked in a closed ring. See carbocyclic compounds; heterocyclic compounds.

Ringer's fluid Physiological saline containing sodium, potassium, and calcium chlorides; widely used for sustaining animal cells or tissues during *in vitro* biochemical experiments. Named after Sydney Ringer (1835-1910).

RNA See ribonucleic acid.

Rochelle salt See potassium sodium tartrate.

Rochon prism A prism used for obtaining plane-polarized light (see polarization of light) and in other related problems. Such a prism, made of quartz, may be used for work with ultraviolet radiation.

rock In the scientific sense, a rock is any distinct material present in the Earth's crust but, in distinction from a mineral, it need not have a definite chemical composition and may consist of more than one mineral. A rock need not necessarily be hard or stone-like; e.g. clays are regarded as rock materials.

rock crystal A pure natural crystalline form of silica, SiO_2 .

rocket A projectile driven by reaction propulsion that contains its own propellants. A rocket is therefore independent of the Earth's atmosphere both with respect to thrust and oxidant and provides

ROCK SALT

the only known practicable means of propulsion in space. 'Chemical' rockets may be powered by either *solid* or *liquid fuels* that burn in oxygen, while 'nuclear' rockets would be powered by a propulsion reactor (see *nuclear reactor*). 'Multistage' or 'step' rockets are rockets built up of several separate sections, each stage being jettisoned when it has burnt out. The 'booster', or first stage, of a space rocket accelerates the projectile up to the thinner regions of the atmosphere, when subsequent stages take over the propulsion. Thus the necessarily high *escape velocity* is not achieved in denser parts of the atmosphere (which would introduce *friction* heating problems), moreover as each stage is jettisoned the projectile becomes substantially lighter, and higher velocities can be achieved with less thrust (see *specific impulse*). Deceleration of rockets is obtained by the use of *retro-rockets*. 'Rocket motors' are also used on certain types of aircraft for take-off, or when a high thrust is required for a short period.

rock salt Natural crystalline *sodium chloride*, NaCl.

Rodinal* A photographic *developer* consisting of an *alkaline solution* of *para*-aminophenol, $\text{NH}_2\text{C}_6\text{H}_4\text{OH}$, with sodium bisulphite, NaHSO_3 .

roentgen The amount of *X-* or *gamma-radiation* that will produce ions carrying 2.58×10^{-4} *coulomb* of electricity of either sign in 1 cm^3 of dry air. Named after Willhelm Konrad Roentgen (1845-1923).

Roentgen rays See *X-rays*.

rongalite A compound of sodium sulfoxylate and *formaldehyde*, $\text{NaHSO}_2 \cdot \text{HCHO}$. Used as a *reducing agent* in dyeing.

root (math.) 1. One of the equal *factors* of a number or quantity. The square root, $\sqrt{\quad}$ or $\sqrt{\quad}$, is one of two equal factors; e.g. $9 = 3 \times 3$ or -3×-3 ; hence $\sqrt{9} = \pm 3$. Similarly the *cube* or third root is denoted by $\sqrt[3]{\quad}$ etc. It may also be denoted by a fractional *index*; thus $\sqrt[2]{x} = x^{\frac{1}{2}}$. 2. The root of an *equation* is a value of the unknown quantity that satisfies the equation.

root mean square value of alternating quantity If y is a periodic *function* of t , of period T , the root mean square (RMS) value of y is the square root of the mean of the square of y taken over a period. The RMS value I of an *alternating current* is important since it determines the *heat* generated (RI^2) in a resistance R (see *electric current*, *heating effect of*). All ordinary AC measuring instruments give RMS values of current, etc. If the alternating quantity can be represented by a pure *sine wave*, the RMS value of the quantity A is related to the maximum value a of the quantity (i.e. *amplitude*) by the expression $A = a/\sqrt{2}$. The RMS value of a current is also known as the 'effective value of the current'. Similarly, the RMS value of an alternating *E.M.F.* is known as the 'effective E.M.F.'.

root mean square value of variable RMS. The square root of the average of the squares of a number of values, given by:

$$\text{RMS} = \sqrt{\frac{\text{(Sum of squares of the individual values of the variable)}}{\text{(total number of values)}}}$$

Rose's metal An alloy of 50% bismuth, 25% lead, and 25% tin; m.p. 94°C.

rosin Colophony. A yellowish *amorphous resin* obtained as a residue from the *distillation* of *turpentine*. R.d. 1.08, m.p. 120°-150°C. Used in varnishes, soaps, and soldering fluxes. See also *ester gum*.

Rotameter* A device for measuring the rate of flow of *fluids*; it consists of a small float that is suspended by the fluid in a vertical calibrated tube. The weight of the float gives a measure of the rate of flow.

rotary converter An *alternating current electric motor* mechanically coupled to a *direct current generator*. Used for converting an AC supply into DC.

rotary dispersion See *optical activity*.

rotor The rotating part of a *turbine*, *electric motor*, or *generator*.

rubber An elastic *solid* obtained from the *latex* of the *Hevea brasiliensis* tree. Raw natural rubber consists mainly of the *cis*-form of *polyisoprene*, $(\text{CH}_2\text{CH}:\text{C}(\text{CH}_3):\text{CH}_2)_n$, a *hydrocarbon polymer*, with *molecular weight* of about 300 000. Nearly all rubber articles are made by 'compounding' raw rubber, i.e. mixing it with other ingredients and then *vulcanizing* it in moulds by heating with sulphur and *accelerators*.

rubber, synthetic A class of *synthetic elastomers* made from *polymers* or *copolymers* (see *polymerization*) of simple *molecules*. See *butyl rubber*; *neoprene*; *nitrile rubber*; *styrene-butadiene rubber* (SBR); *silicone rubber*; *stereoregular rubbers*.

rubidium Rb. Element. A.W. 85.47. At. No. 37. A soft, extremely *reactive*, white *metal* resembling sodium. R.d. 1.53, m.p. 38.9°C. It occurs in a few rare *minerals*. See also *rubidium-strontium dating*.

rubidium-strontium dating A method of *dating* some rocks, used for specimens over 10^9 years old. It is based on the *decay* of rubidium-87 (*half-life* 5×10^{11} years) to yield strontium-87. An estimate of the sample's age is given by the ratio of the two *isotopes*.

ruby A red form of *corundum*, Al_2O_3 , that owes its colour to traces of chromium. Used in *lasers* and as a gem stone.

rules of Fajans Rules that describe the conditions determining whether an *electrovalent* or a *covalent bond* (see *valence*, *electronic theory of*) will be formed between *atoms*. Fajans' rules state that an *electrovalent bond* will be replaced by a *covalent bond* if: (1) the charge on either of the *ions* resulting from an *electrovalent donation* of *electrons* is large (i.e. if more than 1 or 2 electrons are donated); or (2) the volume of the *cation* is small or that of the *anion* is large.

RUST

rust An *hydrated oxide* of iron, mainly $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, formed on the surface of iron when it is exposed to moisture and air.

ruthenium Ru. Element. A.W. 101.07. At. No. 44. A hard brittle *metal*, r.d. 12.2, m.p. 2450°C . It occurs together with platinum. Used in *alloys* and as a *catalyst*.

rutile A crystalline form of natural *titanium dioxide*, TiO_2 .

Rydberg constant A constant relating to those atomic *spectra* that are similar to the hydrogen *atom* spectrum (see *Balmer series*). The Rydberg constant for hydrogen is $1.096\,77 \times 10^7 \text{ m}^{-1}$. The general Rydberg formula is:

$$1/\lambda = R(1/n^2 - 1/m^2)$$

where R is the Rydberg constant and n and m are positive *integers*. The quantity R_1hc , where h is *Planck's constant* and c is the *velocity of light*, is sometimes treated as a unit of *energy* called the rydberg, symbol Ry , such that $\text{Ry} = 2.179\,72 \times 10^{-18} \text{ joule}$. R_1 is defined as

$$m_e e^4 / 8 \epsilon_0^2 h^3 c$$

where m_e is the *mass* of an *electron* and e its charge; ϵ_0 is the *electric constant*. Named after J. R. Rydberg (1854-1919).

S

saccharide A simple sugar; a *monosaccharide*.

saccharimeter An apparatus for determining the *concentration* of a sugar solution by measuring the *angle* of rotation of the plane of vibration of polarized light passing through a tube containing the solution. See *optical activity*; *polarization of light*.

saccharin $C_6H_4SO_2CONH$. A white, crystalline, sparingly soluble solid; m.p. $227^{\circ}C$. When pure, it has about 550 times the sweetening power of sugar, but has no food value, and may have harmful effects if used to excess. Manufactured from *toluene*, $C_6H_5CH_3$. Also used in the form of a sodium salt called 'saccharin sodium', $C_6H_4COSO_2NNa.2H_2O$.

saccharometer A type of *hydrometer* used for finding the *concentration* of sugar solutions by determining their *density*; usually graduated to read the percentage of sugar direct.

saccharose See *sucrose*.

safety lamp Davy lamp. An oil-lamp that will not ignite inflammable gases, e.g. *methane* (fire-damp). It has a cylinder of wire gauze acting as a chimney; the heat of the flame is conducted away by the gauze, and while fire-damp will burn inside the gauze, the temperature of the gauze does not rise sufficiently high to ignite the gas outside.

safrole $CH_2:CHCH_2C_6H_3O_2CH_2$. A yellowish crystalline substance, m.p. $11.2^{\circ}C$., b.p. $234.5^{\circ}C$., used in the manufacture of perfumes, flavours, and soaps.

sal ammoniac See *ammonium chloride*, NH_4Cl .

salicin $CH_2OHC_6H_4OC_6H_{11}O_5$. A colourless soluble glucoside, m.p. $200^{\circ}C$., used as an *antipyretic* and *analgesic*.

salicylate A salt or ester of *salicylic acid*.

salicylic acid $OH.C_6H_4COOH$. A white crystalline solid, m.p. $159^{\circ}C$. Used as an antiseptic and in the form of a derivative as *aspirin*.

saline Containing salt, especially the salts of *alkaline metals* and *magnesium*. A 'saline solution' is a solution of salts in water, especially one which is *isotonic* with body fluids.

salinometer A type of *hydrometer* used for determining the *concentration* of salt solutions by measuring their *density*.

salt (chem.) A chemical compound formed when the hydrogen of an acid has been replaced by a metal. A salt is produced, together with water, when an acid reacts with a base. Salts are named according to the acid and the metal from which the salt is derived; thus *sodium sulphate* is a salt derived from sodium and *sulphuric acid*.

SALT, COMMON

salt, common See *sodium chloride*, NaCl.

salt bridge A tube of *potassium chloride* in the form of a gel, used to connect two *half cells* without mixing the *electrolytes*.

saltcake See *sodium sulphate*, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.

salt effect See *salting-out*.

salting-out *Precipitation* of a dissolved substance by addition of another (usually a *salt*) that lowers its *solubility*; e.g. *soaps* can be salted-out by common salt (*sodium chloride*) from solutions in water.

saltpetre Nitre. See *potassium nitrate*.

salts of lemon Potassium quadroxalate, $\text{KH}_3\text{C}_4\text{O}_8 \cdot 2\text{H}_2\text{O}$. A white, soluble, poisonous, crystalline salt. Used for removing ink-stains.

salt volatile Commercial 'ammonium carbonate', actually consisting of a mixture of ammonium bicarbonate, NH_4HCO_3 , ammonium carbamate, $\text{NH}_4\text{O} \cdot \text{CO} \cdot \text{NH}_2$, and ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$.

samarium Sm. Element. A.W. 150.35. At. No. 62. R.d. 7.536, m.p. 1072°C . See *lanthanides*.

sand Hard, granular powder, generally composed of granules of impure *silica*, SiO_2 .

sandstone Rock formed from sand or quartz particles cemented together with clay, calcium carbonate, and iron oxide.

sandwich compound A complex in which an atom of a *transition element*, often chromium, is sandwiched between two parallel benzene rings.

saponification The *hydrolysis* of an ester; the term is often confined to the hydrolysis of an ester using an *alkali*, thus forming a *salt* (a soap in the case of some of the higher fatty acids) and the free alcohol.

saponification number One of the characteristics of a fat or oil; the number of milligrams of *potassium hydroxide* required for the complete *saponification* of one gram of the fat or oil.

saponins *Glucosides*, derived from plants, that form a lather with water. Used as foaming agents and *detergents*.

sapphire A natural crystalline form of blue, transparent corundum (*alumina*, Al_2O_3); the colour being due to traces of cobalt or other metals.

satellites Bodies that rotate in orbits round other bodies of greater mass under the influence of their mutual *gravitational field*. Particularly bodies, or moons, that rotate around planets. E.g. the Moon is a satellite of the Earth. See also *satellites, artificial*.

satellites, artificial In 1957 the first man-made artificial satellite was launched by Russia into orbit around the Earth. This, and subsequent Russian and American artificial satellites, have been used to obtain, and radio back to Earth, information concerning conditions prevailing in the upper atmosphere and the ionosphere. Valuable information has also been obtained relating to cosmic

rays, the *density of matter* and the frequency of *meteors in space*, the shape and *magnetic fields* of the Earth, and the nature of solar radiations. As a result of the earlier American satellites the *Van Allen radiation belts* were discovered.

'Communication' satellites are artificial Earth satellites used for relaying radio, television, and telephone signals around the curved surface of the Earth. 'Passive' satellites merely reflect the transmissions from their surfaces, while 'active' satellites are equipped to receive and retransmit signals. See also *synchronous orbit*.

saturated compound (chem.) A *compound* that does not form *addition compounds*; a compound the *molecule* of which contains no double or multiple *valence bonds* between the atoms.

saturated solution A *solution* that can exist in *equilibrium* with excess of *solute*. The *saturation concentration* is a function of the *temperature*.

saturated vapour A *vapour* that can exist in *equilibrium* with its *liquid*.

saturated vapour pressure The *pressure* exerted by a *saturated vapour*. This pressure is a function of the *temperature*.

saturation The characteristic of a *colour* that is determined by the degree to which it departs from white and approaches a pure spectral colour.

Saturn (astr.) A *planet*, with ten small *satellites*, and surrounded by characteristic rings (see *Saturn's rings*). Its *orbit* lies between those of *Jupiter* and *Uranus*. Mean distance from the *Sun*, 1427.01 million kilometres. *Sidereal period* ('year'), 29.46 years. Mass, approximately 95.14 times that of the *Earth*, diameter 119 300 kilometres. Surface temperature, about -150°C .

Saturn's rings Three concentric rings, probably composed of the remains of a broken-up *satellite*, which are seen round the *planet Saturn*.

sawtooth waveform A waveform in which the shape resembles the teeth of a saw. The voltage builds slowly and linearly up to a maximum value and then falls perpendicularly to zero in each cycle.

SBR See *styrene-butadiene rubber*.

scalar quantity Any quantity that is sufficiently defined when the magnitude is given in appropriate units. Compare *vector*.

scalene (Of a *triangle*) having three unequal angles and sides. (Of a *cone*) having its *axis* inclined to its *base*.

scaler Scaling circuit. An *electronic* device or circuit that produces an output *pulse* when a prescribed number of input pulses has been received. If the prescribed number is two (or ten) the circuit is referred to as a binary (or decade) scaling circuit or scaler.

scandium Sc. Element. A.W. 44.956. At. No. 21. R.d. 2.99, m.p. 1539°C . A rare *metal* that occurs in small quantities as the oxide Sc_2O_3 .

scanning The repeated and controlled traversing of: (1) a *mosaic* in a television camera, or a screen in a *cathode-ray tube*, with an

SCANNING ELECTRON MICROSCOPE

electron beam; (2) an airspace with a *radar aerial*; or more generally (3) any area or volume with a moving detector in order to measure some quantity or detect some object.

scanning electron microscope See *electron microscope*.

scattering The deflection of any *radiation* as a result of its interaction with *matter*. E.g. the change in direction of a particle or *photon* on interacting with a *nucleus* or *electron*. If the scattered particle or photon loses *energy* by causing *excitation* of the struck nucleus the scattering is said to be 'inelastic'; if energy is not lost in this way the scattering is 'elastic'. See also *scattering of light*.

scattering of light When a *beam of light* traverses a material medium, scattering of the beam takes place. Two types of scattering occur: (1) by random *reflection*; i.e. small particles suspended in the medium act as tiny *mirrors* and, being randomly orientated with respect to the beam, produce random reflections. This type occurs when the size of the particles is large in comparison with the *wavelength* of the light: (2) by *diffraction*; this occurs when particles that are small compared with the wavelength of the light are present in the medium. Owing to diffraction phenomena, the particles act as centres of radiation and each particle scatters the light in all directions. In this type, the degree of scattering is proportional to the inverse fourth power of the wavelength of the light. Thus, blue light is scattered to a greater extent than red. The blue colour of the sky is due to scattering by the actual *molecules* of the *atmosphere*.

Scheele's green A bright green *precipitate*, probably consisting of cupric arsenite, $\text{Cu}_3(\text{AsO}_8)_2 \cdot 2\text{H}_2\text{O}$. Used as a *pigment* and *insecticide*. Named after Karl Wilhelm Scheele (1742-86).

scheelite A naturally occurring *ore* of tungsten, CaWO_4 .

Schiff's reagent A reagent used to test for *aldehydes*. It consists of the dye *magenta*, which has been decolorized with *sulphur dioxide* or *sulphurous acid*. Aldehydes oxidize the reduced form of the dye back to its original colour. Named after Hugo Schiff (1834-1915).

schlieren photography In a fast moving *fluid* in which there is *turbulent flow*, streaks (German, 'Schliere') become visible because they have a different *density* and *refractive index* from the bulk of the fluid. These streaks can be photographed using *spark photography*, or other high speed photographic methods.

Schmidt telescope (camera) A type of astronomical reflecting *telescope* consisting of a primary spherical *mirror* with a correcting plate at, or near, its *centre of curvature*. This plate corrects for *aberration*, *coma*, and *astigmatism*, enabling a wide area of the sky to be photographed with good *definition*. The instrument is not used visually but *images* are photographed on a curved surface. See Fig. 36. Named after Bernhard Schmidt (1879-1935).

SCHMIDT TELESCOPE

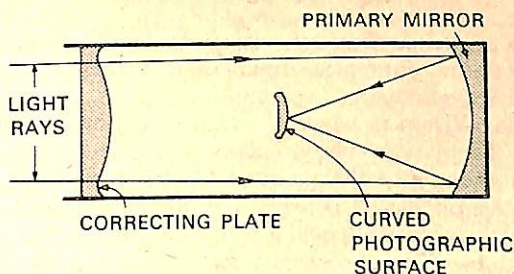


Figure 36.

Schottky defect See *vacancy*.

Schrödinger wave equation The wave equation used in wave mechanics to describe the behaviour of a particle in a field of force. It is based on de Broglie's concept that every moving particle is associated with a wave of wavelength h/mv (where h is Planck's constant and m and v are the mass and velocity of the particle). In three dimensions the equation has the form:

$$\nabla^2\psi + (8\pi^2m/h^2)(E - U)\psi = 0$$

where ∇^2 is the Laplace operator, ψ is the wave function, E is the total energy and U is the potential energy of the particle. See also *eigenfunction*. Named after Erwin Schrödinger (1887-1961).

Schwartzchild radius See *black hole*.

Schweitzer's reagent A deep blue solution of a copper ammine in cupric hydroxide, $\text{Cu}(\text{OH})_2$. A solvent for cellulose; formerly used for this purpose in the obsolete cuprammonium process for rayon manufacture.

scintillation counter A device in which light flashes, produced by a scintillator (see *phosphor*) when exposed to ionizing radiation, are converted into electrical pulses by a photomultiplier, thus enabling the number of ionizing events to be counted.

scintillation spectrometer A device for determining the energy distribution of a given radiation. It consists of a scintillation counter that incorporates a pulse height analyser.

scintillator See *phosphor*.

sclerometer An instrument for measuring the hardness of a material, usually by measuring the pressure required to scratch it, or by measuring the height to which a standard ball will rebound from it when dropped from a fixed height. See *Mohs scale* and *Brinell test*.

SCLEROPROTEIN

scleroprotein A class of complex, *insoluble*, fibrous *proteins*, (e.g. *keratin*, *collagen*, *elastin*) that occur in the surface coatings of animals and form the framework binding *cells* together in animal tissues.

-scope Suffix applied to names of instruments for observing or watching, usually as distinct from measuring. E.g. *telescope*.

scopolamine See *hyoscine*.

scotopic vision Vision in which the rods in the eye are the principal receptors. This type of vision occurs when the level of light is low and colours cannot be distinguished. Compare *photopic vision*.

screen grid A grid placed between the *anode* and *control grid* of a *thermionic valve*, usually held at a fixed positive potential.

scruple 1/24 ounce Troy. See *Troy weight*.

sea-water The approximate composition (not including inland seas such as the Dead Sea) is water, 96.4%; common salt, NaCl, 2.8%; *magnesium chloride*, MgCl_2 , 0.4%; *magnesium sulphate*, MgSO_4 , 0.2%; *calcium sulphate*, CaSO_4 , and *potassium chloride*, KCl, 0.1% each.

sebacic acid $\text{HOOC}(\text{CH}_2)_8\text{COOH}$. A *dibasic crystalline fatty acid*, m.p. 134.5°C ., used in the manufacture of *plasticizers* and *resins*.

secant A straight line cutting a *circle* or other curve.

secant (trigonometry) See *trigonometrical ratios*.

second 1. The SI unit of time defined as the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium-133 atom. Symbol s. 2. A measure of angle: 1/60 of a minute.

secondary cell See *accumulator*.

secondary colour A colour e.g., green or orange, obtained by mixing two *primary colours*.

secondary emission of electrons When a primary beam of rapidly moving *electrons* strikes a *metal* surface, secondary electrons are emitted from the surface. The effect is of importance in the *thermionic valve*, the *photomultiplier*, etc. In the thermionic valve, the emission occurs when the electrons strike the *anode*, and may be suppressed or controlled in multi-electrode tubes (*tetrode*, *pentode*) by various grids called the *suppressor* and *screen grids*.

second derivative (math.) The *derivative* of a derivative, written d^2x/dy^2 . E.g. *acceleration* (*a*) is the second derivative of distance (*s*) with respect to time (*t*), or the first derivative of *velocity* (*v*) with respect to time, i.e., $a = d^2s/dt^2 = dv/dt$.

sector See *circle*.

secular variation of magnetic declination If the Earth's magnetic North Pole is considered to rotate round the geographical North Pole, completing a cycle in about 930 years, a representation of a steady variation of *magnetic declination*, known as the secular variation, will be seen. Thus, the magnetic declination in London is at present

westerly, and decreasing until it is due to become zero at the beginning of the twenty-second century.

sedative A *drug* that reduces nervousness and excitement.

sedimentation The process of separating an *insoluble solid* from a *liquid* in which it is suspended by allowing it to fall to the bottom of the containing vessel, with or without agitation or *centrifuging*.

Seebeck effect If two wires of different *metals* are joined at their ends to form a *circuit* and the two junctions are maintained at different *temperatures*, an *electric current* flows round the circuit. Compare *Peltier effect*. Named after T. J. Seebeck (1770-1831).

seeding Impfing. The addition of fine particles to a *solution* to induce crystallization. Each particle (often a tiny crystal of the *solute*) acts as a *nucleus* upon which the new crystal grows.

Seger cone A device for estimating the approximate *temperature* of a furnace; the cones are made of material softening at a definite temperature. Named after Hermann Seger (d. 1893).

segment See *circle* and *sphere*.

seismograph An instrument for recording earthquake shocks.

seismology The scientific study of earthquakes and the phenomena associated with them.

selenate A salt or ester of *selenic acid*.

selenic acid H_2SeO_4 . A strongly corrosive crystalline *acid*, m.p. 58°C ., with properties resembling those of *sulphuric acid*.

selenide A *binary compound* of *selenium*.

selenium Se. Element. A.W. 78.96. At. No. 34. It is a non-metal resembling sulphur in its chemical properties. R.d. 4.81, m.p. 217°C . It exists in several *allotropic forms*. The so-called 'metallic' selenium, a silvery-grey crystalline *solid*, varies in electrical *resistance* on exposure to *light* and is used in *photoelectric cells*. Selenium occurs as *selenides* of metals, together with their *sulphides*; used in the manufacture of *rubber* and of *ruby glass*.

selenium cell A type of *photoelectric cell* consisting of a layer of selenium covered by a thin transparent layer of gold. Light falling on the cell produces a voltage by the *photovoltaic effect*.

selenium rectifier A *rectifier* that consists of alternate layers of iron and selenium in contact.

selenology The scientific study of the *Moon*, its nature, origin, and movements. Now that samples of the Moon's surface are available for study on Earth, selenology has become a branch of *chemistry* as well as *astronomy*.

self-absorption The decrease in the *radiation* from a *radioactive* material caused by the absorption of a part of the radiation by the material itself.

self-exciting (Of a *generator*.) Having *magnets* that are excited by *current* drawn from the output of the generator.

SELF-INDUCTANCE

self-inductance The coefficient of *self-induction*.

self-induction The *magnetic field* associated with an *electric current* cuts the *conductor* carrying the current. When the current changes, so does the magnetic field, resulting in an induced *E.M.F.* (See *induction, electromagnetic*). This phenomenon is called self-induction. The induced *E.M.F.* is proportional to the rate of change of the current, the constant of proportionality being called the coefficient of self-induction, or the self-inductance. The magnitude of the self-inductance is a function only of the geometry of the electrical circuit and can be calculated in a few simple cases. The derived *SI unit* of inductance is the *henry*. Symbol *L*.

semiconductor An electrical *conductor* whose *resistance* decreases with rising *temperature* and the presence of impurities, in contrast to normal metallic conductors for which the reverse is true. Semiconductors, which may be *elements* or *compounds*, include germanium, silicon, selenium, and lead-telluride. In general, semiconductors consist of *covalent crystals*, 'ideal' examples of which at the *absolute zero* of temperature would pass no *electric current* as all the *valence electrons* would be held by the covalent bonds. At normal temperatures, however, some of the electrons have sufficient thermal *energy* to break free from the bonds leaving *holes*. Electrons liberated in this way will have random thermal motions, but in an imposed *electric field* there will be a net drift against the field resulting in so called *N-type conductivity*. The behaviour of the holes is more complex, but they may be regarded as positive charges free to move about the crystal giving rise to *P-type conductivity*. The total current passed by such an *intrinsic semiconductor* is therefore the sum of the electron current and the hole current in the direction of the field. A rise in temperature will create more *carriers*, due to more bonds being broken by thermal energy, and thus lower resistance. The foregoing refers to 'ideal' crystals, but real crystals will have inherent *defects, dislocations*, and impurities that will produce additional carriers (see *extrinsic semiconductor*). In practical semiconductors impurities are added in controlled quantities during crystal growth, the number of *valence electrons* of the impurity *atoms* determining whether the *majority carriers* will be P- or N-type. A P-N *semiconductor junction* is formed when there is a change along the length of a crystal from one type of impurity to the other. At a P-N junction an internal electric field is created between the charged impurity *ions* of the two types. This field is sufficient to prevent the drift of electrons from the N-side to the P-side of the junction, and the drift of holes in the opposite direction. If an external positive *voltage* is applied to the P-side and a negative voltage to the N-side, the internal field can be overcome and a substantial current will flow as a result of the tendency of the majority carriers on each side to

migrate to the other side: the magnitude of the current will depend upon the applied voltage. Reversing the voltage increases the effect of the internal field and the only current to flow will be the small number of *minority carrier* electrons on the P-side carried over to the N-side; similarly minority carrier holes will be carried from the N- to the P- regions. The reverse current is therefore small and does not depend upon the applied voltage. The P-N junction is thus a very efficient *rectifier* and is widely used for this purpose (see *semiconductor diode*); it is also the basis of the *transistor*.

semiconductor diode A *semiconductor* device, either based on a *semiconductor junction* or on point contact, with two *electrodes*. It is used for rectification. Compare *rectifying valve*.

semiconductor junction A plane that separates two layers of a *semiconductor* each of which have different electrical characteristics. For example, a P-N junction separates the P-region (in which *holes* are the *majority carriers*) from the N- region (in which *electrons* are the majority carriers).

semipermeable membrane A membrane allowing the passage of some substances and not of others; a partition that permits the passage of pure *solvent molecules* more readily than those of the dissolved substance. E.g. copper ferrocyanide, $\text{Cu}_2\text{Fe}(\text{CN})_6$, is permeable to *water*, but only very slightly permeable to dissolved substances. Used as a partition between *solution* and solvent in osmotic measurements (see *osmotic pressure*) and in *dialysis*.

semipolar bond A *valence bond* in which two *electrons* are donated by one *atom* (usually nitrogen or oxygen) to another atom, which requires both of them to complete its *octet*. This is equivalent to one electrovalent bond and one covalent bond (see *valency*, *electronic theory of*) and is therefore called a semipolar bond.

sensitization (phot.) Photographic *silver bromide* "emulsions" are in themselves sensitive only to short-wave visible light (violet and blue), so that light of longer wavelength (e.g. red, green) is not registered. Emulsions for correct rendering of relative intensities of light of different *colours* (*panchromatic*), and for use in colour photography, can be rendered sensitive to radiation in particular wavelength ranges by the use of certain dyes, known as sensitizers, which absorb radiation in these ranges (including *infrared*) and are able to utilize the energy absorbed in the breakdown of the silver bromide. *Cyanine dyes* are particularly useful for this purpose.

sensitometer An instrument for measuring the sensitivity of a photographic plate or film (see *photography*).

separation energy The *energy* required to remove a particle (a *proton* or a *neutron*) from a particular atomic *nucleus*.

septavalent Heptavalent. Having a *valence* of seven.

sequestering agent See *chelation*; *sequestration*.

SEQUESTRATION

sequestration The process of 'locking-up' metal ions in complexes to make them ineffective. The sequestering agents used for this purpose are usually chelating agents. See *chelation*.

series (math.) A sequence of numbers or mathematical expressions such that the n th term may be written down in general form, and any particular term (say, the r th) may be obtained by substituting r for n ; e.g. x^n is the general term of the series $1, x, x^2, x^3 \dots x^n$.

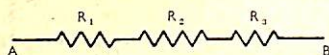


Figure 37.

series, resistances in If a number of conductors of electricity are connected in series, i.e. one after the other, so that the current flows through each in turn, the total resistance is the sum of the separate resistances of the conductors. See Fig. 37.

serine A white crystalline amino acid, m.p. 246°C ., that occurs in many proteins. See Appendix, Table 5.

Serpuk process A process for the fixation of atmospheric nitrogen. Aluminium is made to react with nitrogen to form aluminium nitride, which is then decomposed by steam to give ammonia.

serum The liquid that remains after the clotting and removal of blood cells and fibrin from the blood; any similar body liquid.

servomechanism A mechanism that converts a small low-powered mechanical motion into a mechanical motion requiring considerably greater power. The output power is always proportional to the input power, and the system may include a negative feedback device (usually electronic).

sesame oil A yellow oil obtained from sesame seeds, m.p. -6°C ., r.d. 0.919, used in the manufacture of margarine and cosmetics.

sets A set is a group of objects or elements that have at least one common characteristic. If these objects or elements are represented by m_1, m_2, m_3 , etc., then $\{m_1, m_2, m_3, \dots\} = M$ is the way of writing that m_1, m_2, m_3 , etc. belong to the set M .

$m_1 \in M$ means that m_1 is a member of set M . If some of the objects or elements m_1, m_2, m_3 , etc. can be classified into a subset A , and some others into subset B , then $A \subset M$ (read as subset A is contained in set M) and $B \subset M$ (read as subset B is contained in set M). If, for example, m_2 belongs to both subsets A and B , then $m_2 \in A \cap B$, means that m_2 is a member of subsets A and B , or m_2 belongs to the intersection of subsets A and B . The mathematical theory dealing with relationships between sets is known as 'set theory'.

sexivalent Hexivalent. Having a *valence* of six.

sextant An instrument for determining the *angle* between two objects (e.g. horizon and *star*). Commonly employed for determining the radius of a *position circle*.

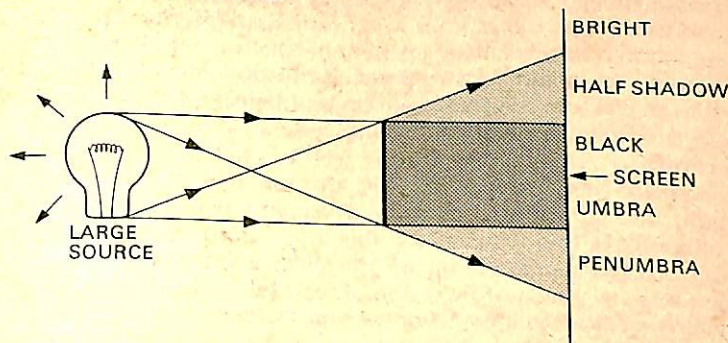


Figure 38.

shadow A dark patch formed by a body that obstructs *rays of light*. A shadow cast by an object in front of a *point source* of light is a sharply defined area; a source of light of appreciable size produces two distinct regions, the *umbra* or full shadow, and the *penumbra* of half-shadow. See Fig. 38.

shadow bands A series of wavy *shadow* bands that fall across the *Earth* just before and after *totality* in a solar *eclipse*. It is due to differences in *density* of the *atmosphere*.

shear A *stress* applied to a body in the *plane* of one of its faces.

shellac A yellowish natural *resin* secreted by the lac insect (*Laccifer lacca*), which is parasitic on certain trees native to India and Thailand. It consists of several *polyhydroxy organic acids* (predominantly aleuritic acid, $C_{16}H_{32}O_5$, and shellolic acid, $C_{15}H_{20}O_6$) together with 3%-5% of wax. Shellac produces smooth, durable *films* from alcoholic *solutions* and *alkaline* dispersions, which adhere to a variety of surfaces; used in varnishes, polishes, leather dressings, and sealing wax. Owing to its electrical insulation properties it is used in insulating varnishes and in Micanite* (see *mica*).

shells, electron According to the interpretation of *quantum mechanics*, the *electrons* contained within an *atom* circle round the *nucleus* in *orbits* at various distances from the nucleus. These orbital electrons may be visualized as forming a series of concentric shells: electrons in the same shell have the same principal *quantum number*, *n*. The shells are designated by the letters K-P (equivalent to values of *n* from 1-6) in order of increasing distance from the nucleus. The number of electrons in each shell is restricted (see *Pauli's exclusion*

principle), but each shell is capable of containing $2n^2$ electrons. Table 7 in the Appendix, gives the electronic configuration of the commoner *elements*. Within each shell, electrons are further classified into sub-shells (or *energy* sub-levels) according to their orbital *angular momentum*, which is represented by their azimuthal quantum number, l . The separate sub-shells are distinguished by the letters s, p, d, and f (corresponding to values of l of 0, 1, 2, and 3). E.g. an electron designated 4f, has a principal quantum number of 4 (N shell) and an azimuthal quantum number of 3 (f sub-shell).

sherardizing A method of plating iron or *steel* with zinc, to form a *corrosion* resistant coating. The iron or steel is heated in contact with zinc powder to a *temperature* slightly below the *melting point* of zinc. At this temperature the two metals amalgamate forming internal layers of zinc-iron *alloys* and an external layer of pure zinc.

shock wave A very narrow region of high *pressure* and *temperature* in which air flow changes from *subsonic* to *supersonic*. See also *sonic boom*.

shooting star See *meteor*.

short circuit If a *potential difference* exists between two points A and B (e.g. the terminals of an electrical supply), a system of *conductors* connecting A and B constitutes a *circuit*. If now A and B are placed in contact, or joined by a conductor of much lower *resistance* than the rest of the circuit, most of the current will flow direct between A and B, which are then said to be short-circuited or 'shorted'.

short sight See *myopia*.

shower The production by one high-energy particle, originating from *cosmic rays* or *accelerators*, of several fast particles. 'Cascade' showers (or soft showers) consist of *electrons*, *positrons*, or *photons* formed by successive *pair productions* or *radiative collisions*. 'Penetrating' showers contain *nucleons* and *muons* capable of penetrating up to about 20 cm of lead. 'Auger' showers (or extensive showers) extend over areas of up to 1000 square metres.

shunt, electrical A device for reducing the amount of *electric current* flowing through a piece of apparatus, such as a *galvanometer*. It consists of a *conductor* connected in *parallel* with the apparatus.

sideband The band of *frequencies* lying on either side of a *modulated carrier wave*; the width of each sideband is equal to the highest modulating frequency.

side chain (chem.) An *aliphatic radical* or group attached to a *straight chain* or to a *benzene ring* or other cyclic group in the *molecule* of an *organic compound*. E.g. in *toluene*, $C_6H_5.CH_3$, the *methyl group*, CH_3 , is a side chain attached to a benzene ring.

sidereal day The period of a complete rotation of the *Earth* upon its *axis*, with respect to the *fixed stars*. It is 4.09 minutes shorter than a *mean solar day*.

- sidereal period of a planet** The 'year' of a *planet*. The actual period of its revolution round the *Sun*. See Appendix, Table 4.
- sidereal year** See *year*.
- siderite** 1. Natural ferrous carbonate, FeCO_3 . An important ore of iron. 2. A *meteorite* consisting of *metals* (principally iron) and *metallic compounds*.
- siemens** The *SI unit* of electric *conductance* defined as the conductance of a circuit or element that has a resistance of 1 *ohm*. The unit was formerly called the reciprocal ohm or *mho*. Symbol S. Named after Sir William Siemens (1823-83).
- Siemens-Martin process** See *open-hearth process*.
- sigma bond** σ bond. See *orbital*.
- sigma particle** Σ -particle. An *elementary particle* classified as a *hyperon*. It exists in three charged states: positive, negative, and neutral. See Appendix, Table 6.
- sigma pile** An assembly consisting of a *neutron* source and a *moderator*, without any *fissile* material, which is used to study the properties of moderators.
- sign, algebraical** The plus or minus sign, + or -, indicating opposite senses or directions; thus +5 is numerically equal, but opposite in sign, to -5.
- silage** A stored form of cattle-fodder produced by a limited *fermentation* of green fodder pressed down and stored in a pit. *Lactic acid* is formed during the process.
- silanes** A class of silicon *hydrides* of the general formula $\text{Si}_n\text{H}_{2n+2}$, forming a *homologous series* analogous to the *alkanes*.
- silica** Silicon dioxide. SiO_2 . A hard, *insoluble*, white or colourless *solid* with a high *melting point* (1610-1713°C.). It is very abundant in nature in the forms of *quartz*, *rock-crystal*, *flint*, and as *silicates* in rocks. Used in the form of a white powder in the manufacture of *glass*, *ceramics*, and *abrasives*.
- silica gel** A form of *silica*, SiO_2 , with a highly porous structure capable of adsorbing (see *adsorption*) 40% of its *weight* of water from a *saturated vapour*. Used in *gas drying* and as a *catalyst* support.
- silicates** A vast range of compounds, *salts* of or derived from *silicic acids*, that may be conveniently regarded as compounds of *silica* with various metal *oxides*. Most of the Earth's crust is composed of the silicates of calcium, aluminium, magnesium, and other metals. Various glasses, ceramics, and cements consist largely of silicates. See also *aluminosilicates*.
- silicic acids** Various *hydrated* forms of *silica*, obtained in colloidal or *gel* form by the action of acids on soluble *silicates* in solution. E.g. metasilicic acid, H_2SiO_3 ($\text{SiO}_2 \cdot \text{H}_2\text{O}$), and orthosilicic acid, H_4SiO_4 ($\text{SiO}_2 \cdot 2\text{H}_2\text{O}$), giving rise to the meta- and orthosilicates.
- silicol process** The manufacture of hydrogen by the action of *sodium hydroxide* (caustic soda, NaOH) *solution* on *silicon*.

SILICON

- silicon** Si. Element. A.W. 28.086. At. No. 14. A non-metal similar to carbon in its chemical properties. It occurs in two *allotropic forms*: a brown *amorphous* powder and dark grey *crystals*; r.d. 2.33, m.p. 1410°C. It is the second most abundant element in the *Earth's crust*, occurring in sand and rocks as *silica* and as *silicates*. The element is obtained by reducing silica with carbon in an electric furnace. The pure element is used in *semiconductors*; it is also used in *alloys* and in the form of *silicates* in *glass*. *Silicones* are also widely used.
- silicon carbide** SiC. A hard black *insoluble* substance, m.p. 2700°C., used as an *abrasive* and in *resistors* required to withstand high temperatures.
- silicon chip** See *integrated circuit*.
- silicone rubbers** Rubber-like *polymers* of various *organosilicon compounds*, such as *siloxanes* (in particular, dimethylsiloxane, $(\text{CH}_3)_2\text{SiO}$), having valuable characteristics, such as high stability over wide ranges of temperature, outstanding water repellence, high resistance to chemical action, good electrical properties, etc.
- silicones** A term originally applied to *compounds* of the general formula R_2SiO , where R stands for *hydrocarbon radicals*. They are now defined as polymeric (see *polymerization*) *organic siloxanes* of the general type $(\text{R}_2\text{SiO})_n$. Used as lubricants, for water-repellent finishes, high-temperature resisting *resins*, and lacquers.
- silicon tetrachloride** SiCl_4 . A colourless fuming *liquid*, b.p. 57.57°C., used in making *silicon compounds* and *smokescreens*.
- silk** A thread-like substance produced by the silkworm. It consists mainly of the *proteins* sericin and fibroin.
- siloxanes** A group of *compounds* with the general formula R_2SiO , where R stands for an *organic group* or hydrogen. See also *silicones*.
- silver** Ag. Element. A.W. 107.87. At. No. 47. A white, rather soft, extremely malleable metal; r.d. 10.5, m.p. 961.93°C. It occurs as the metal, and as *argentite* or silver glance, Ag_2S ; *horn silver*, AgCl ; and other *compounds*. It is extracted by alloying with lead, and then separating the lead by *cupellation* and other methods. Used in coinage and jewellery; *compounds* are used in *photography*.
- silver bromide** AgBr . A pale yellow, *insoluble salt*, m.p. 434°C., used in *photography*.
- silver chloride** AgCl . A white *insoluble salt*, m.p. 455°C., that occurs naturally as *horn silver* (cerargyrite) and is used in *photography* and *antiseptics*.
- silver glance** See *argentite*.
- silver iodide** AgI . A yellow *insoluble salt*, m.p. 558°C., that occurs naturally as iodyrite and is used in *photography*, medicine, and in seeding clouds to produce artificial rain.
- silver nitrate** Lunar caustic. AgNO_3 . A white *soluble crystalline salt*, m.p. 209°C. Used in marking-inks, medicine, and chemical analysis.

silver plating The process of depositing a layer of silver on the surface of metal articles, usually by electrolytic methods. See *electroplating*.

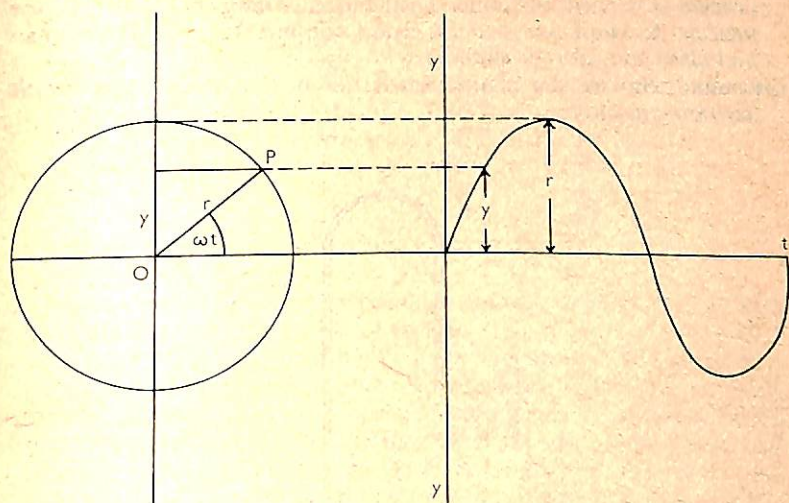


Figure 39.

simple harmonic motion S.H.M. A point is said to move in simple harmonic motion when it oscillates along a line about a central point, O, so that its *acceleration* towards O is always proportional to its distance from O. Thus, if a point P moves in a *circle*, centre O and radius r , with a constant *angular velocity* ω , the projection of P on any diameter will move in S.H.M. If the distance from O of the projection of P on a vertical diameter is y , at time t , then a *graph* of y against t will give a 'sine wave' of *amplitude* r and *equation* $y = r \sin \omega t$. (See Fig. 39) This equation may be rewritten in the more general form:

$$y = r \sin 2\pi(t/T - x/\lambda)$$

where T is the *period* of the wave, λ its *wavelength* and x the distance it has travelled from O in time t .

simultaneous equations A set of *equations* in which the values of the *variables* will satisfy all the equations; if the equations contain n variables, then to obtain a *solution* there must be at least n equations.

sine See *trigonometrical ratios*.

sine wave Sinusoidal wave. A wave that has an equation in which one

SINTERING

variable is proportional to the *sine* of the other. See *simple harmonic motion*.

sintering Compressing *metal* particles into a coherent *solid* body. The process is carried out under *heat*, but at a *temperature* below the *melting point* of the metal. Certain non-metals, such as *ceramics* and *glass*, may also be sintered.

sinusoidal Having the characteristics of a *sine* wave. See *simple harmonic motion*.

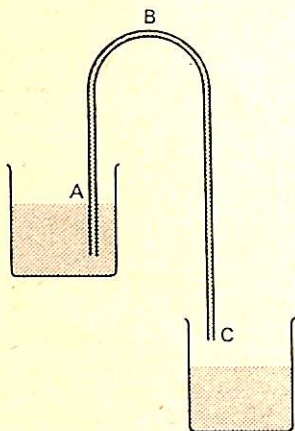


Figure 40.

siphon A bent tube used for transferring *liquid* from one level to a lower level via a third level higher than either. If the shorter arm of an inverted U-tube filled with liquid is immersed below the liquid surface in A (see Fig. 40), liquid will flow from A to C through the tube. The siphon depends for its action on the fact that the *pressure* at A tending to force the liquid up the tube is $P - P_{ab}$ and the pressure acting upwards on the liquid at C is $P - P_{ac}$, where P = external atmospheric pressure, and P_{ab} and P_{ac} are the pressures due to the *weights* of the liquid columns AB and AC respectively. Hence flow from A to B will occur provided BC is greater than AB.

SI units *Système International d'Unités*. An internationally agreed *coherent* system of *units*, derived from the *m.k.s. system*, now in use for all scientific purposes and thereby replacing the *c.g.s. system* and the *f.p.s. system*. The seven basic units are; the *metre* (symbol m), *kilogram* (kg), *second* (s), *ampere* (A), *kelvin* (K), *mole* (mol), and *candela* (cd). The *radian* (rad) and *steradian* (sr) are

<i>Factor</i>	<i>Name of Prefix</i>	<i>Symbol</i>	<i>Factor</i>	<i>Name of Prefix</i>	<i>Symbol</i>
10	deca-	da	10^{-1}	deci-	d
10^2	hecto-	h	10^{-2}	centi-	c
10^3	kilo-	k	10^{-3}	milli-	m
10^6	mega-	M	10^{-6}	micro-	μ
10^9	giga-	G	10^{-9}	nano-	n
10^{12}	tera-	T	10^{-12}	pico-	p
10^{15}	peta-	P	10^{-15}	femto-	f
10^{18}	exa-	E	10^{-18}	atto-	a

supplementary units. Derived units having special names and symbols are the *hertz* (Hz), *newton* (N), *joule* (J), *watt* (W), *coulomb* (C), *volt* (V), *farad* (F), *ohm* (Ω), *weber* (Wb), *tesla* (T), *henry* (H), *lumen* (lm), *lux* (lx), *pascal* (Pa), *siemens* (S), *becquerel* (Bq), and *gray* (Gy). Decimal multiples are given in the table (where possible a prefix representing 10 raised to a power that is a multiple of three should be used). See Appendix, table 1.

skatole C_9H_9N . A white *soluble* crystalline substance, m.p. $265^\circ C$., with a strong odour, used in the manufacture of perfumes.

skip distance There is a minimum angle of *incidence* at the *ionosphere* below which a *sky wave* of a given *frequency* is not reflected, but is transmitted through to outer *space*. Consequently there is a region surrounding a *radio* transmitter within which no sky wave can be received. The minimum distance at which reception of the sky wave is possible is called the skip distance.

sky wave Ionospheric wave. A *radio* wave may travel from transmitting *aerial* to receiving aerial by one of two paths: either directly along the ground (see *ground wave*), or by reflection from the *ionosphere*. In the latter case it is called a sky wave or ionospheric wave.

slag Non-metallic material obtained during the *smelting* of metallic *ores*; it is generally formed as a molten mass floating on the molten *metal*.

slaked lime See *calcium hydroxide*.

slaking The addition of *water*.

slate A natural form of aluminium silicate formed from *clay* hardened by *pressure*.

slide rule A mathematical instrument used for rapid calculations; it consists of a grooved ruler with a scale, with another similarly marked ruler sliding inside the groove. Multiplication and division are carried out by adding or subtracting lengths on the two rulers, the divisions of which are in a logarithmic scale. Slide rules have been largely replaced by pocket calculators.

SLOW NEUTRON

slow neutron A neutron whose kinetic energy does not exceed about 10 electron-volts.

slug A unit of mass in the f.p.s. system defined as the mass that will acquire an acceleration of 1 ft/sec² when acted upon by a force of 1 lb. 1 slug is equal to 32.174 lbs.

slurry A thin paste consisting of a suspension of a solid in a liquid.

smelting The extraction of a metal from its ores by a process involving heat. Generally the process is one of chemical reduction of the oxide of the metal with carbon in a suitable furnace.

smetic crystals Liquid crystals in which the molecules are arranged in layers with their axes parallel and perpendicular to the plane of the layers. See also *cholesteric crystals*; *nematic crystals*.

smog A dark, thick, dust- and soot-laden, sulphurous fog that, under certain meteorological conditions, pollutes the atmosphere of some industrial cities and the lungs of their inhabitants.

smoke A suspension of fine particles of a solid in a gas; smoke from coal consists mainly of fine particles of carbon.

Snell's law See *refraction, laws of*.

soap A mixture of the sodium salts of stearic acid, C₁₇H₃₅COOH, palmitic acid, C₁₅H₃₁COOH, and oleic acid, C₁₇H₃₃COOH; or of the potassium salts of these acids ('soft soap'). Soaps are made by the action of sodium or potassium hydroxide on fats, the process of hydrolysis or saponification giving the soap, with glycerol as a by-product. The term soap is also applied to fatty acid salts of metals other than sodium or potassium, although such compounds are unlike the ordinary soaps.

soda Any of various sodium compounds; washing soda, sodium carbonate, Na₂CO₃·10H₂O; baking soda, sodium hydrogen carbonate, NaHCO₃; caustic soda, sodium hydroxide, NaOH.

soda ash The common name for anhydrous sodium carbonate, Na₂CO₃.

soda-lime A solid mixture of sodium hydroxide, NaOH, and calcium hydroxide, Ca(OH)₂; made by slaking quicklime (see calcium oxide) with a solution of sodium hydroxide and drying by heat.

soda nitre Caliche. Impure natural sodium nitrate.

soda water Water containing carbon dioxide, CO₂, under pressure; releasing the pressure lowers the solubility of the gas, and thus causes effervescence.

sodium Na. (Natrium.) Element. A. W. 22.9898. At.No. 11. A soft silvery-white metal, r.d. 0.971, m.p. 97.5°C. It is very reactive, tarnishing rapidly in air. It reacts violently with water, forming sodium hydroxide and hydrogen gas. Compounds are very abundant and widely distributed; the commonest is sodium chloride, NaCl (common salt). The metal is used in the preparation of organic compounds and as a coolant in some types of nuclear reactor.

- sodium azide** NaN_3 . A colourless crystalline substance, used in the manufacture of *explosives*.
- sodium benzoate** $\text{C}_6\text{H}_5\text{COONa}$. A white *soluble* powder, used as an *antiseptic* and a food preservative.
- sodium bicarbonate** NaHCO_3 . See *sodium hydrogen carbonate*.
- sodium carbonate** Washing soda. $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. A white crystalline *soluble salt*, m.p. 850°C . Used in the household, in the manufacture of *glass, soap, paper*, and for *bleaching*.
- sodium chlorate** NaClO_3 . A colourless *soluble* crystalline substance, m.p. $248\text{--}261^\circ\text{C}$., used in the manufacture of *explosives*, as a *mordant, oxidizing agent*, and an *antiseptic*.
- sodium chloride** Common salt, salt. NaCl . A white crystalline *soluble salt*, m.p. 801°C . It occurs extensively in *sea water* and as *halite*.
- sodium cyanide** NaCN . A white *soluble deliquescent* substance, m.p. 563.7°C ., used in *electroplating*, case-hardening, and fumigation.
- sodium cyclamate** $\text{C}_6\text{H}_{11}\text{NHSO}_3\text{Na}$. A white crystalline *soluble* powder, formerly used as a sweetening agent in soft drinks and for diabetics, but now banned from such use owing to possible side-effects.
- sodium dichromate (bichromate)** $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$. An orange *soluble* crystalline substance, m.p. 356.7°C . (after losing its water of crystallization at 100°C .), used as a *mordant, corrosion inhibitor, oxidizing agent*, and in *electroplating*.
- sodium dithionite** Sodium hydrosulphite. $\text{Na}_2\text{S}_2\text{O}_4$. A white crystalline *soluble* powder, used as a *reducing agent* and in *bleaching*.
- sodium ethoxide** Sodium ethylate. $\text{C}_2\text{H}_5\text{ONa}$. A white *hygroscopic* substance, used in organic synthesis.
- sodium fluoride** NaF . A colourless crystalline substance, m.p. 988°C ., used in the *fluoridation* of water and as an *insecticide*.
- sodium hydrogen carbonate** Sodium bicarbonate. NaHCO_3 . A white *soluble* powder, used in *baking powder, fire extinguishers*, and in medicine as an *antacid*.
- sodium hydrogen glutamate** Monosodium glutamate. MSG. $\text{HOOC}(\text{CH}_2)_2\text{CH}(\text{NH}_2)\text{COONa}$. A white *soluble* crystalline substance, used to intensify the flavour of foods.
- sodium hydroxide** Caustic soda. NaOH . A white *deliquescent solid*, m.p. 318.4°C ., that dissolves in water to give an *alkaline solution*. Used in the manufacture of *soap, rayon*, and other chemicals.
- sodium hypochlorite** NaOCl . A white unstable crystalline solid, m.p. 18°C ., usually kept in aqueous solution. Used in *bleaching paper and textiles* and as an *oxidizing agent, antiseptic, and fungicide*.
- sodium nitrate** NaNO_3 . A white *soluble* crystalline salt, m.p. 306.8°C ., that occurs naturally as *Chile saltpetre*. Used as a *fertilizer* and in the manufacture of *nitric acid* and *explosives*.
- sodium perborate** $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$. A white *soluble* crystalline substance, m.p. 63°C ., used in *bleaching* and as a disinfectant.

SODIUM PEROXIDE

- sodium peroxide** Na_2O_2 . A yellow powder, formed when sodium *metal* burns in air. It reacts with water to give *sodium hydroxide* and oxygen gas. Used in *bleaching* and as an *oxidizing agent*.
- sodium phosphate** Three principal *compounds* are called by this name.
1. Sodium dihydrogen orthophosphate, NaH_2PO_4 , a white *soluble* crystalline substance used in *electroplating* and dyeing.
 2. Disodium hydrogen orthophosphate, Na_2HPO_4 , a white *soluble* crystalline substance used in *dyes*, *fertilizers*, *detergents*, *baking powder*, and medicine.
 3. Trisodium orthophosphate, $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$, a colourless *soluble* crystalline substance used in *detergents*, and in the manufacture of *paper* and water softeners.
- sodium silicate** Na_2SiO_3 . A white *soluble* crystalline *salt*, used in the household as 'water-glass', in fireproofing textiles, and in the manufacture of *paper* and *cement*.
- sodium sulphate** Glauber's salt. Saltcake. $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$. A white *soluble* crystalline *salt*. Used in the manufacture of *soap*, *detergents*, and *dyes*.
- sodium sulphide** Na_2S . An orange *soluble deliquescent* substance, m.p. 1180°C ., used in the manufacture of *soaps* and *dyes*.
- sodium sulphite** Na_2SO_3 . A white crystalline *soluble* powder, used as a food preservative, in *bleaching*, and in *photography*.
- sodium tetraborate** (correctly disodium tetraborate) Borax sodium biborate, sodium pyroborate. $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$. A white, *soluble* crystalline *salt*, occurring naturally as *tincal*. On heating it loses *water of crystallization* and melts to a clear glass-like solid (see *borax bead test*). Used as an *antiseptic*, in fireproofing, as a *flux*, and in the manufacture of *glass* and *ceramics*.
- sodium thiocyanate** NaSCN . A colourless *deliquescent* crystalline substance, m.p. 287°C ., used in medicine.
- sodium thiosulphate** Sodium hyposulphite, *hypo*. $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$. A white crystalline very *soluble salt*, used in *photography* for fixing.
- sodium-vapour lamp** A luminous *discharge* obtained by passing an *electric current* between two *electrodes* in a tube containing sodium *vapour* at low *pressure*. Used in street lighting as the characteristic yellow light is less absorbed by fog and mist than *white light*.
- soft iron** Iron containing little carbon, as distinct from *steel*; iron that does not retain *magnetism* permanently, but loses most of it when the magnetizing field is removed.
- soft radiation** *Ionizing radiation* of relatively long *wavelength* and low penetrating power, as opposed to 'hard' radiation, which is of shorter wavelength and high penetrating power.
- soft soap** See *soap*.
- software** The *programs* used in a *computer*, especially the general programs supplied by the computer manufacturer. The 'hardware' is the actual equipment of the computer itself.

soft water Water that forms an immediate lather with soap. See *hard water*.

soil Soils vary enormously in their chemical composition. The *inorganic* portion of a soil is composed of *silicates* of various *metals*, mainly of aluminium, but also of iron, calcium, magnesium, etc., free *silica* (sand) and other *inorganic* matter, depending on the source. *Organic* matter in the soil is mainly derived from decomposed plants; much of it is in the form of a class of black, sticky substances known collectively as *humus*.

sol See *colloidal solution*.

solar cell (battery) An electric cell that converts energy from the Sun into *electrical energy*. It usually consists of a *semiconductor* device sensitive to the *photovoltaic effect*; e.g. a P-N *semiconductor junction* in a crystal of silicon. Used in artificial *satellites* and *space probes* to power *electronic* equipment. See also *solar energy*.

solar constant The energy that would (in the absence of the *atmosphere*) be received per minute by an area of 1 sq cm placed at the mean distance of the *Earth* from the *Sun* and at right angles to the incident *radiation*; its value is approximately 2 *calories* per minute per square centimetre. In *SI units* the solar constant is equal to about 1400 *joules* per second per square *metre*.

solar day The variable interval between two successive returns of the *Sun* to the *meridian*. The mean solar day is the average value of this. See *time measurement*.

solar energy Energy from the Sun. Life on Earth relies almost entirely on solar energy. It provides the energy needed for plant growth by *photosynthesis* and animals obtain their energy from plants and other animals. *Fossil fuels* also depend ultimately on *photosynthesis*. *Hydroelectric power*, wind power, and wave power all depend on the Sun's energy through its influence on the weather.

The amount of energy falling on the Earth from the Sun is given by the *solar constant*. If all this energy could be harnessed, every inhabitant of the Earth could burn 12 000 2kW heaters continuously. But, in fact, very little direct use has been made of solar energy. Broadly, there are two ways of using solar energy directly. The thermal methods involve absorbing the Sun's radiation on a metal plate and using the absorbed heat to raise the temperature of water. This is the principle of the domestic solar heater. Non-thermal methods use devices, such as *solar cells*, to produce electricity from sunlight. This is the method used in spacecraft, satellites, etc. In order for solar cells to be useful as a source of energy on Earth (domestically or industrially) their price would have to drop substantially to make them competitive with other energy sources.

solar flares Short high *temperature* outbursts seen as bright areas in the *chromosphere* of the Sun. Jets of particles (known as the *solar wind*) and strong *radio frequency electromagnetic radiations* (see

SOLAR PARALLAX

radio astronomy) are emitted during solar flares. Solar flares are associated with *sunspots* and usually cause magnetic and *radio* disturbances on *Earth*.

solar parallax The *angle* subtended by the mean equatorial radius of the *Earth* at a distance of one *astronomical unit*.

solar prominences Large eruptions of luminous gas that rise several thousands of kilometres above the *Sun's chromosphere*.

solar system The system of nine *planets*—*Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, *Saturn*, *Uranus*, *Neptune* and *Pluto*—and of the belt of *asteroids* revolving in elliptical *orbits* round the *Sun*. The orbits are nearly circular, and lie very nearly in the same *plane*. See Appendix, Table 4.

solar wind Streams of electrically charged particles (*protons* and *electrons*) emitted by the *Sun*, predominantly during *solar flares* and *sunspot* activity. Some of these particles become trapped in the *Earth's* magnetic field (see *magnetism*, *terrestrial*) forming the outer *Van Allen radiation belt*, but some penetrate to the *upper atmosphere* where they congregate in narrow zones in the region of the *Earth's* *magnetic poles* producing auroral displays (see *aurora borealis*).

solar year See *year*.

solder An *alloy* for joining *metals*. Soft solders are alloys of tin and lead in varying proportions, they melt in the range 200–300°C.; brazing solders are usually composed of copper and zinc, with melting points over 800°C.

solenoid A coil of wire wound uniformly on a cylindrical former, having a length that is large compared with its radius. When a current I is passed through the solenoid, a uniform *magnetic field* H is produced inside the coil parallel to its *axis*. If I is in *amperes* and n is the number of turns per *metre*, $H = nI$ amperes per *metre*.

solid (math.) A three-dimensional figure, having length, breadth, and thickness; a figure occupying *space* or having a measurable *volume*.

solid angle The ratio of the area of the surface of the portion of a *sphere* enclosed by the conical surface forming the angle, to the square of the radius of the sphere. See *steradian*.

solidifying point The constant *temperature* at which a *liquid* solidifies under a given *pressure*, usually the standard *atmosphere*.

solid solution A solid *homogeneous mixture* of two or more substances. E.g. some *alloys* are solid solutions of the *metals* in each other, the process of *solution* having taken place in the molten state.

solid state The *physical state of matter* in which the constituent *molecules*, *atoms*, or *ions* have no *translatory motion* although they vibrate about the fixed positions that they occupy in a *crystal lattice*. A solid is said to possess *cohesion*, remaining the same shape unless changed by external *forces*. Certain solids are not crystalline, they are then said to be *amorphous*. A crystalline solid

has a definite *melting point* at which it becomes a *liquid*; amorphous solids have no precise melting point, but when heated become increasingly pliable until they assume the properties usually associated with liquids, they may therefore be thought of as 'supercooled' liquids.

solid state physics The branch of *physics* that deals with the nature and properties of *matter* in the *solid state*. The term is often used to refer especially to the study of the properties of *semiconductors* and 'solid state devices', i.e. *electronic* devices consisting entirely of solids, without moving parts, *gases*, or heated *filaments*, e.g. *semiconductors*, *transistors*, *integrated circuits*, etc.

solstice The time (or, more accurately, the point) at which the *Sun* reaches its greatest *declination* North or South. The points are situated upon the *ecliptic* half-way between the *equinoxes*; the times are approximately 21 June and 21 December.

solubility The extent to which a *solute* will dissolve in a *solvent*. Usually expressed in grams per 100 g of solvent at a specified *temperature*.

solubility product The product of the *concentrations* of the *ions* of a dissolved *electrolyte* when in *equilibrium* with undissolved substance. For sparingly *soluble* electrolytes, the solubility product is a constant for a given substance at a given *temperature*. When the solubility product for a given compound is exceeded in a *solution*, some of it is precipitated until the product of the ionic concentrations falls to the constant value.

soluble Capable of being dissolved (usually in *water*).

solute A substance that is dissolved in a *solvent* to form a *solution*.

solution A *homogeneous* molecular *mixture* of two or more substances of dissimilar molecular structure; the word is usually applied to solutions of *solids* in *liquids*. Other types of solutions include *gases* in liquids, the *solubility* of gases decreasing with rise in *temperature*; *gases* in solids; liquids in liquids; and solids in solids (e.g. some *alloys*). See *solid solutions*.

solvation The combination of *solvent molecules* with *molecules* or *ions* of the *solute*. The compound so formed is called a 'solvate'.

Solvay process Ammonia-soda process. An industrial preparation of *sodium carbonate* or *washing-soda*, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, from common salt, NaCl , and *calcium carbonate*, CaCO_3 . By the action of *ammonia*, NH_3 , and *carbon dioxide* (obtained by heating CaCO_3) on a salt solution, the less soluble *sodium hydrogen carbonate*, NaHCO_3 , is precipitated. The action of *heat* on this compound gives the required *sodium carbonate*, while the *ammonia* is recovered from solution by the action of the *lime* (*calcium oxide*). Named after Ernest Solvay (1838-1922).

solvent A substance (usually *liquid*) having the power of dissolving other substances in it; that component of a *solution* that has the

SOLVENT EXTRACTION

same *physical state* as the solution itself. E.g. in a solution of *sugar* in *water*, *water* is the solvent, while *sugar* is the *solute*.

solvent extraction See *extraction*.

somatic Pertaining to the body. *Somatic cells* are the cells of which the body of an *organism* is constructed, as opposed to the reproductive or germ cells. See also *mutation*. In another sense the word refers to the body as opposed to the mind: e.g. psychosomatic medicine is the study of the influence of psychological factors upon physiological illness.

sonar SOund NAvigation Ranging. An apparatus for locating submerged objects by transmitting a high *frequency sound wave* and collecting the reflected wave. The time for the wave to travel to the object and return gives an indication of the depth.

sonic boom The loud noise created by the *shock wave* set up by an aircraft or missile travelling at *supersonic speeds*. A subsonic aircraft produces pressure waves ahead of itself, which travel at the speed of *sound*, and 'clear a path' for the oncoming aircraft. In supersonic flight the aircraft overtakes the pressure waves so that a shock wave *cone* is created with the nose of the aircraft at its *vertex*. In level flight the intersection of the shock wave cone with the ground produces a *hyperbola*, at all points along which the sonic boom is simultaneously experienced; subsequently the boom will be experienced at all points within the hyperbola's path over the ground.

sorbent Any agent used for *sorption*.

sorbite 1. The constituent of *steel* produced when *martensite* is *tempered* above 450°C., consisting of *ferrite* and finely divided *cementite*. 2. Sorbitic pearlite. The constituent of steel produced by the decomposition of *austenite* when cooled at a slower rate than will yield *troostite* and a faster rate than will yield *pearlite*.

sorbitol $\text{CH}_2\text{OH}(\text{CHOH})_4\text{CH}_2\text{OH}$. A white crystalline sweet *soluble polyhydric alcohol*, m.p. 110°C. (for the *dextrorotatory compound*), obtained from *dextrose*; used as a *sugar* substitute and in the manufacture of synthetic *resins*.

sorption *Adsorption* (a surface process) or *absorption* (a volume process). The term is often used when the mechanism of a particular process is not known or is not specified.

sound A physiological sensation received by the ear. It is caused by a vibrating source with a *frequency* in the range 20-20 000 *hertz* and is transmitted as a longitudinal pressure wave *motion* (see *longitudinal waves*) through a material medium such as air. See also *ultrasonics*; *infrasound*.

sound, velocity of The *velocity* of propagation of *sound waves* (see *wave motion*). This velocity is a function of the *temperature* and of the nature of the propagating medium. In gases it is independent of

the *pressure*. In air at 0°C. it is 332 metres per second or approximately 760 miles per hour.

source The *electrode* in a *field-effect transistor* from which electrons or *holes* enter the inter-electrode space.

Soxhlet extraction apparatus A device for extracting the *soluble* portion of any substance by a continuous circulation of the boiling *solvent* through it.

space That part of the boundless four-dimensional *continuum* in which *matter* can be physically (rather than temporally) extended. (See *space-time*.) More colloquially, space (or 'outer' space) is that part of the *Universe* that lies beyond the Earth's *atmosphere*, in which the density of matter is very low.

spacecraft A vehicle capable of travelling in *space*.

space probe A *rocket*-propelled missile that has sufficient *velocity* to escape from the Earth's *atmosphere*. Space probes are used for making measurements of conditions within the *solar system* that cannot be made by terrestrial observation. The measurements are made by miniaturized *electronic* equipment within the probe, the results of which are signalled back to Earth by *radio*. A Moon-probe, or Lunar-probe, is one intended to study the *Moon* and its environment.

space-reflection symmetry See *parity*.

space-time The development of the theory of *relativity* has led to the disappearance of a clear-cut distinction between a three-dimensional *space* and an independent *time*; in the modern view, space and time are considered as being welded together in a four-dimensional space-time *continuum*.

spallation A *nuclear reaction* in which a high *energy* incident particle, or *photon*, causes several particles or fragments to be emitted by the target *nucleus*. The *mass number* and *atomic number* of the target nucleus may thus be reduced by several units.

spark See *electric spark*.

spark chamber A device for detecting radiation or *elementary* particles. A 'spark counter' consists of a pair of electrodes with a high potential difference between them, placed close together. If a particle passes between anode and cathode it causes a spark and, at the moment of discharge, a measurable drop in the anode voltage. The passage of particles through the device is recorded photographically or electronically. The 'spark chamber' usually has several pairs of electrodes and is often filled with neon.

spark coil See *induction coil*.

spark-plug A device for providing an *electric spark* for exploding the *mixture* of air and *petrol vapour* in the cylinder of the *internal-combustion engine*.

sparking potential Sparking voltage. The difference in *potential* (i.e.

SPARK PHOTOGRAPHY

the voltage) required for an *electric spark* to pass across a given gap. See *Paschen's law*.

spark photography Flash photography. *Photography* in which the source of *light* is an *electric spark* usually of predetermined duration. Photographs are taken in the dark (or low light) and the *camera lens* is left open, thus the exposure time can be made very short and rapidly moving objects can be photographed.

sparteine $C_{15}H_{26}N_2$. A bitter colourless *alkaloid*, m.p. $30^{\circ}C.$, used in medicine.

special theory of relativity See *relativity, theory of*.

specific When the adjective 'specific' is used before the name of an extensive physical quantity, it implies 'divided by mass'. E.g. *specific heat capacity* is *heat capacity* per unit mass. When the extensive quantity is denoted by a capital letter (e.g. *V* for *volume*), the specific quantity is usually denoted by the corresponding small letter ($v = V/m$ for *specific volume*). In some older physical quantities the word has had other meanings (e.g. *specific resistance*), but such uses are now deprecated. See *specific gravity*.

specific activity *a*. The *activity* per unit *mass* of a pure *radioisotope*; or the activity of a radioisotope in a material per unit mass of that material. It is expressed in *curies* per g or *disintegrations* per second per kg.

specific charge The *electric charge* to *mass* ratio of an *elementary particle*.

specific gravity The former term for the ratio of the density of a substance to that of water. As the word *specific* now has a different usage, the term *relative density* is now used for this concept.

specific heat capacity *Specific heat*. *c*. *Heat capacity* divided by *mass*.

The quantity of *heat* required to raise the *temperature* of unit mass of a substance by one degree. It is expressed in *joules* per kg per *kelvin* (*SI units*), *calories* per gram per $^{\circ}C.$ (*c.g.s. units*), or *British thermal units* per lb per $^{\circ}F$ (*f.p.s. units*).

The two most important specific heat capacities of a gas are (1) that measured at constant pressure, c_p , and (2) that measured at constant volume, c_v . c_p is greater than c_v because when a gas is heated at constant pressure it has to do work against the surroundings in expanding. The ratio c_p/c_v , usually denoted by γ (gamma) varies from 1.66 for *monatomic* gases to just over 1 for more complex *molecules*. The value of gamma therefore gives some indication of the number of atoms in the molecules of a gas.

specific impulse A term used in connexion with *rockets*. The ratio of the *thrust* produced (in lbs) to the rate of *fuel* consumption (lbs per sec.). The specific impulse therefore has the dimension of 'seconds', and may be thought of as the length of time one pound of *propellant* would last if expended at a rate that would continuously produce one pound of thrust.

specific resistance See *resistivity*.

specific surface The total surface area per unit mass of a given substance, e.g. a powder or a porous material. It is usually expressed in $\text{m}^2 \text{kg}^{-1}$ or square centimetres per gram. It represents the actual surface area available for processes, such as *adsorption*, and may be very large for fine powders and highly porous substances.

specific volume The *volume*, at a specified *temperature* and *pressure*, occupied by unit mass (usually 1 kg) of a substance. The *reciprocal* of the *density*.

spectral lines See *line spectrum*.

spectral series The emission *spectrum* of any substance may be analysed into one or more groups of *frequencies* (or *wavelengths*), the frequencies in each group forming a series. For example, the spectrum of the hydrogen *atom* possesses series given by the expression:

$$\nu = k(1/n_0^2 - 1/n^2),$$

where ν is the frequency of the spectral *lines* and k is a constant. For the different series, n_0 takes the values 1, 2, 3, 4, etc. For any one value of n_0 , n may have all *integral* values from $n_0 + 1$ upwards, the expression then giving the frequencies of all the lines in that particular series. See also *Balmer series*; *Rydberg constant*.

spectral types Spectral classes. The classification of *stars* based on the *spectrum* of the *light* they emit. The system now used is the Harvard classification, which comprises ten types of star.

spectrograph 1. An instrument by which *spectra* may be photographed.
2. A photograph taken by means of such an instrument. See *spectrographic analysis*.

spectrographic analysis An investigation of the chemical nature of a substance by the examination of its *spectrum*, using the fact that the position of emission and absorption *lines* and *bands* in the spectrum of a substance is characteristic of it.

spectroheliograph An instrument used to photograph the *Sun* with *light* of a particular *wavelength*.

spectrometer 1. A type of *spectroscope* so calibrated that it is suitable for the precise measurements of *refractive indices*. 2. An instrument for measuring the *energy* distribution of a particular type of *radiation*, e.g. a *scintillation spectrometer*.

spectrophotometer A *photometer* for comparing two *light* radiations *wavelength* by *wavelength*.

spectroscope An instrument for *spectrographic analysis* or the observation of *spectra*. The simplest type is the prism spectroscope. This consists of a *collimator*, which collects the light from the source and throws it onto the face of a glass *prism*. The *spectrum* so formed, after refraction by the prism, is viewed through a *telescope*. The angle between the collimator and the telescope can be varied.

SPECTROSCOPIC BINARY

spectroscopic binary A *binary star* system that cannot be seen as two stars by a *telescope*, but which show a *Doppler effect* in their *line spectrum* as these stars revolve about each other. See *visual binary*.

spectroscopy The study of *matter* and *energy* by the use of a *spectroscope*. See *spectrographic analysis*.

spectrum The result obtained when *electromagnetic radiations* are resolved into their constituent *wavelengths* or *frequencies*. In the visible region (i.e. *light waves*) a well-known example is provided by the coloured bands produced when white light is passed through a *prism* or *diffraction grating*. (See *spectrum colours*). Spectra formed from bodies emitting radiations are termed *emission spectra*. When white light is passed through a semi-transparent medium, selective absorption of radiations of certain wavelengths or bands of wavelengths takes place; the spectrum of the transmitted light is called an *absorption spectrum*. A continuous spectrum is one in which all wavelengths, between certain limits, are present. A *line spectrum* is one in which only certain wavelengths or 'lines' appear. The emission and absorption spectra of a substance are fundamental characteristics of it and are often used as a means of identification. Such spectra arise as a result of transitions between different *stationary states* of the *atoms* or *molecules* of the substance, electromagnetic waves being emitted or absorbed simultaneously with the transition. The frequency ν of the emitted or absorbed radiation is given by $E_1 - E_2 = h\nu$, where E_1 and E_2 are the *energies* of the first and second states respectively between which the transition takes place, and h is *Planck's constant*. When E_1 is greater than E_2 , electromagnetic waves are emitted; in the converse case, they are absorbed.

Colour of Light	Wavelength/ 10^{-7} metres	Frequency/ 10^{14} hertz
Red	6.470–7.000	4.634–4.284
Orange	5.850–6.470	5.125–4.634
Yellow	5.750–5.850	5.215–5.125
Green	4.912–5.750	6.104–5.215
Blue	4.240–4.912	7.115–6.104
Violet	4.000–4.240	7.495–7.115

spectrum colours The *colours* visible in the continuous *spectrum* of *white light*. These colours, their *wavelengths* and *frequencies* are given in the table.

specular reflection Perfect or regular reflection of *electromagnetic radiation*, e.g. *light*. It occurs whenever the reflecting surface is flat to approximately $1/8$ of a *wavelength* of the radiation incident upon it.

speculum A reflecting *mirror*, especially a metallic mirror (see *speculum metal*) used in a reflecting *telescope*.

- speculum metal** An alloy of 2/3 copper and 1/3 tin; used for *mirrors* and *reflectors*. See *speculum*.
- speed** The ratio of the distance covered to the time taken by a moving body. Speed in a specified direction is *velocity*.
- spelter** Commercial zinc, about 97% pure, containing lead and other impurities.
- spermaceti** A white, waxy *solid* consisting mainly of cetyl palmitate, $C_{15}H_{31}COOC_{16}H_{33}$. M.p. 40° - $50^{\circ}C$. It is obtained from the head of the sperm whale. Used in the manufacture of *soaps* and *cosmetics*.
- spermatocyte** A male *gametocyte* that undergoes *meiosis* to form spermatids, which change into *spermatozoa*.
- spermatozoon** Sperm. A male *gamete*, four of which are derived by *meiosis* from a single *spermatocyte*.
- sphere** (math.) A *solid* figure generated by the revolution of a semi-circle about a diameter as *axis*. The flat surface of a section cut by a *plane* passing through the centre is a *great circle*; the surface of a section cut off by any other plane is a small circle. The solid cut off by a plane of a great circle is a hemisphere; that cut off by a small circle is a segment. The volume of a sphere having radius r is $4\pi r^3/3$; surface area = $4\pi r^2$.
- spherical aberration** See *aberration*, *spherical*.
- spherical coordinates** Three-dimensional *polar coordinates*. A point in *space* is defined by the length of its *radius vector* and the *angle* this vector makes with two perpendicular *planes*.
- spherical mirror** See *mirrors*, *spherical*.
- spherical triangle** A *triangle* drawn on a spherical surface, bounded by the arcs of three *great circles*. The properties of such triangles differ from those of *plane* triangles; calculations relating to them form the purpose of spherical trigonometry.
- spherical trigonometry** *Trigonometry* that deals with *spherical triangles*.
- spheroid** A *solid* figure generated by an *ellipse* rotating about its minor *axis* (oblate spheroid, a 'flattened sphere') or about its major *axis* (prolate spheroid, an 'elongated sphere').
- spherometer** An instrument for the accurate measurement of small thicknesses, or curvature of spherical surfaces.
- spiegel** *Spiegeleisen*. An alloy of iron, manganese, and carbon, used in the manufacture of *steel* by the *Bessemer process*.
- spin** A term of special significance in *particle physics*. Sub-atomic particles (*electrons*, *neutrons*, *nuclei*, *mesons*, etc.) may possess, in addition to other forms of *energy*, such as energy of translation, energy due to the spinning of the particle about an *axis* within itself. This gives rise to a spin energy term in the quantum analysis (see *quantum mechanics*) of permissible *energy levels*. Quantum considerations limit the magnitude of the spin *angular momentum* of orbital electrons to two values, given by $Jh/2\pi$ or Jh (see

SPINELS

Planck's constant) where J is the spin quantum number, which can have the values $\pm \frac{1}{2}$. The plus and minus signs indicate that the spin can be clockwise or anti-clockwise. For all *baryons* and *leptons* J is half integral ($\frac{1}{2}$, $1\frac{1}{2}$), but for *mesons* and *photons* it is integral (0, 1, 2). See Appendix, Table 6.

spinels A group of *minerals* having the general composition $MO.R_2O_3$, M being a *bivalent metal* (magnesium, ferrous iron, manganese, zinc) and R a *trivalent metal* (aluminium, chromium, ferric iron). See *ferrites*.

spiral galaxies Spiral nebulae. *Galaxies* in which the *stars*, dust, and *gas* clouds are concentrated in the arms of a spiral. Spiral galaxies are believed to have evolved from 'elliptical' galaxies. The *Galaxy* to which the *solar system* belongs is also spiral in form.

spirans Spiro compounds. *Compounds* whose *molecules* contain two rings sharing a common atom.

spirillum A spiral-shaped *bacterium*.

spirits of salt A solution of hydrochloric acid.

spirits of wine See *ethanol*.

spiro compounds See *spirans*.

spontaneous combustion The *combustion* of a substance of low *ignition point*, which results from the *heat* produced within the substance by slow *oxidation*.

sputtering A process for depositing a thin uniform film of a *metal* on to a surface. A disc of the metal to be 'sputtered' is made the *cathode* of a low-pressure discharge system (see *discharge in gases*). The material to be coated is placed between cathode and *anode*, the whole arrangement being enclosed and evacuated to a *pressure* of between 1 and 0.01 mm. A discharge is set up by applying a *voltage* (1000–20 000 volts) between anode and cathode. Metallic *atoms* are ejected from the cathode and are deposited on the surface to be coated.

square 1. A *quadrilateral* having all its sides equal and all its *angles* right angles. **2.** The square of a quantity is that quantity raised to the second *power*, i.e. multiplied by itself.

square root See *root*.

square wave A *wave motion* that alternates between two fixed values for equal lengths of time, the time of transition between the two values being negligible compared to the duration of each fixed value.

squaring the circle The problem of constructing a *square* exactly equal in area to a given *circle*. The exact area of a circle cannot be determined, except in terms of π , which cannot be expressed as an exact fraction or decimal, although any required degree of approximation can be obtained. The problem, therefore, appears to be impossible of solution.

- stabilization** (chem.) The prevention of chemical *decomposition* of a substance by the addition of a 'stabilizer' or 'negative catalyst'.
- stable** (chem.) Not readily decomposed.
- stable equilibrium** (phys.) A body at rest is in *stable equilibrium* if, when slightly displaced, it tends to return to its original position of equilibrium. If the displacement tends to increase, the body is said to be in *unstable equilibrium*. Positions of *stable equilibrium* are positions of *minimum potential energy*; those of *unstable equilibrium* are of *maximum potential energy*.
- stainless steel** A class of chromium steels containing 70%-90% iron, 12%-20% chromium, 0.1%-0.7% carbon.
- stalactite** The downward growth of *calcium carbonate*, CaCO_3 , formed on the roof of a cave by the trickling of water containing calcium compounds.
- stalagmite** The upward growth from the floor of a cave; of the same nature and origin as a *stalactite*.
- stalagmometry** The measurement of *surface tension* by determining the *mass* (or *volume*) of a drop of the *liquid* hanging from the end of a tube.
- Stalloy*** Steel containing 3.5% silicon, having low energy losses due to *hysteresis*. Used in portions of electrical apparatus that are subjected to alternating *magnetic fields*.
- standard atmosphere** See *atmosphere*.
- standard cell** A specially prepared *primary cell*, e.g. the *Weston cell*, characterized by a high constancy of *E.M.F.* over long periods of time. The *E.M.F.* is a function of the *temperature*, and in the *Weston cell* it decreases by about 1 part in 10^5 per 1°C . rise.
- standard deviation** A measure, used in *statistics*, of the scatter of a series of numbers or measurements about their *mean* value. It is defined as the *square root* of the average value of the *squares* of the deviations from their mean value.
- standard electrode** See *hydrogen electrode*; *calomel electrode*.
- standard electrode potential** See *electrode potential*.
- standard temperature and pressure** S.T.P. Standard conditions used for comparing the properties of gases. They are 273.15 kelvins (0°C .) and 101 325 pascals (760 mmHg). See also *N.T.P.*
- standing wave** Stationary wave. A wave produced by the simultaneous transmission of two similar *wave motions* in opposite directions. In *acoustics*, standing waves are caused by *interference* between waves of the same *frequency* in such a way that the combined intensity varies between maxima and minima over the region of interference.
- stand oil** A *drying oil* that has been thickened by heating in an inert atmosphere (without the addition of driers). The thickening is due to *polymerization* of some of the constituents.
- stannate** A *salt* of a *stannic acid*.

STANNIC

stannic Containing *quadrivalent* tin.

stannic acid $\text{SnO}_2 \cdot x\text{H}_2\text{O}$. A series of *amorphous insoluble compounds*.

In α -stannic acid $x = 1$, in β -stannic acid $x = 2$.

stannic chloride SnCl_4 . A colourless fuming *liquid*, b.p. 114.1°C ., used in the manufacture of *mordants*.

stannic oxide SnO_2 . Tin ash. A white *amorphous insoluble* powder, m.p. 1127°C ., used in the manufacture of *glass* and *polishes*.

stannic sulphide Mosaic gold. SnS_2 . A golden *insoluble* powder used in the manufacture of *gold paint*.

stannous Containing *bivalent* tin.

stannous chloride SnCl_2 . A white crystalline substance, m.p. 246°C ., that forms a dihydrate known as 'tin salt', m.p. 37.7°C . Used as a *reducing agent*, a *mordant*, and a *tinning agent*.

stannum See *tin*.

starch Amylum. *Polysaccharides* consisting of chains of *glucose* units arranged in one of two forms: *amylose* and *amylopectin*. Most *natural* starches are mixtures of these two forms (e.g. potato and cereal starches are 20%–30% amylose and 70%–80% amylopectin). Starch is a white tasteless *insoluble* powder that on *hydrolysis* (by boiling with *dilute acids*, or by reacting with *amylases*) gives first *dextrin* and finally *glucose*. Starch is stored by plants in the form of granules and occurs in most seeds.

starch gum See *dextrin*.

stars Heavenly bodies of a similar nature to the *Sun*, i.e. intensely hot, glowing masses that produce their *energy* by *thermonuclear reactions*. The nearest star to the Sun is over 4 *light-years* away; the other *fixed stars* visible to the naked eye are all members of the *Galaxy* and many of them are members of *binary star* systems. The stars are not uniformly distributed throughout the *Universe*, being grouped into enormous clusters called *galaxies*. The nearest galaxy to ours is some 16×10^5 *light-years* away. See also *stellar evolution*.

Stassano furnace See *electric-arc furnace*.

Stassfurt deposits Natural deposits of several *inorganic salts*. The deposit consists of several strata, of a total estimated thickness of 800 *metres*. They are a source of potassium and sodium *compounds* in the form of *carnallite*; also of magnesium bromide, $\text{MgBr}_2 \cdot 6\text{H}_2\text{O}$, and *rock-salt*.

stat- Prefix attached to the name of electrical *units* to indicate the corresponding *electrostatic unit* (e.g. *statcoulomb*).

statcoulomb The *electrostatic unit* of *electric charge* in the c.g.s. system. It is equal to 3.3356×10^{-10} *coulomb*.

states of matter See *physical states of matter*.

static electricity See *electricity, static*.

statics A branch of *mechanics*; the mathematical and physical study of the behaviour of *matter* under the action of *forces*, dealing with cases where no motion is produced.

stationary orbit See *synchronous orbit*.

stationary states A term used in *quantum mechanics*. If only certain energy values or *energy levels* for the total energy of a system are permissible, the energy is said to be *quantized*. These levels are characteristic of the state of the system; such states are called stationary states. A transition from one stationary state to another can occur only with the emission or absorption of energy in the form of *photons*; i.e. *electromagnetic radiation* is emitted or absorbed.

stationary wave See *standing wave*.

statistical mechanics The study of the mechanical properties of large assemblies of particles or components in terms of *statistics*. E.g. the *kinetic theory of gases* treats the *molecules* of a *gas* in terms of statistical mechanics.

statistics The collection and study of numerical facts or data and their interpretation in mathematical terms, with special reference to the theory of *probability*.

stator The fixed part of any *electric motor* or *generator* that contains the stationary magnetic circuits.

steady state theory A theory in *cosmology* that postulates that the *Universe* has always existed in a steady state, that the *expansion of the Universe* is compensated by the continuous creation of *matter*, which is viewed as a property of *space*, and that despite local evolutionary processes, the *Universe* as a whole is not evolving. The rate at which matter would have to be spontaneously created to compensate for the *Universe's* expansion (about $10^{-43} \text{ kg m}^{-3} \text{ s}^{-1}$) is far too low to be measurable and therefore evidence to support this theory has to be sought in other directions. If it could be established that the *density* of matter throughout the *Universe* does not vary with distance or time, this would support the steady state theory rather than its main competitor the *superdense theory*. *Radio astronomy* has been used to assess the density of matter at the most distant parts of the observable *Universe* in order to decide between these two theories. On the present evidence this theory has been discredited in favour of the *superdense theory*.

steam *Water*, H_2O , in the gaseous state; water above its *boiling point*. An invisible gas; the white clouds that are frequently termed 'steam' consist of droplets of *liquid water* formed by the *condensation* of steam.

steam engine A machine utilizing *steam* power; either a steam turbine (see *turbine*) or a reciprocating steam engine, consisting essentially of a cylinder in which a piston is moved backwards and forwards by the expansion of steam under pressure.

steam point The *temperature* at which the maximum *vapour pressure* of *water* is equal to standard atmospheric pressure (see *atmosphere*),

STEARATE

i.e. the normal *boiling point*. In the *Celsius* temperature scale the steam point is given the value of 100°C .

stearate A salt or ester of *stearic acid*.

stearic acid Octadecanoic acid. $\text{C}_{17}\text{H}_{35}\text{COOH}$. A white solid fatty acid, m.p. 69°C ., that occurs as *tristearin* in many fats. Used in the manufacture of soaps, candles, and cosmetics.

stearin *Tristearin*; the term is also sometimes applied to a mixture of *palmitic* and *stearic acids* (see *stearine*).

stearine A hard white waxy solid consisting mainly of *stearic* and *palmitic acids*. It is made by the *saponification* of natural fats.

stearoyl The univalent radical $\text{CH}_3(\text{CH}_2)_{16}\text{CO}-$ (from *stearic acid*).

steel Iron containing from 0.1% to 1.5% carbon in the form of *cementite* (iron carbide Fe_3C). The properties of different steels vary according to the percentage of carbon and of *metals* other than iron present, and also according to the method of preparation. Steel is prepared by the *open-hearth* and *Bessemer processes* and in *electric-arc furnaces*. See also *stainless steel*.

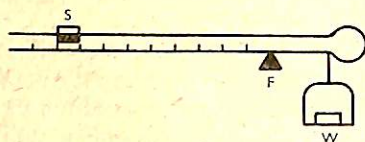


Figure 41.

steelyard A weighing-machine for heavy loads. In principle it consists of a long, rigid bar, with a pan or hook at one end for taking the load to be weighed. The rod is pivoted about a fixed point or fulcrum near the *centre of gravity*, which is fairly near the end with the pan or hook. The other portion of the bar is graduated, and a movable weight slides along this, the weight balanced by it being proportional to its distance from the centre of gravity. See Fig. 41.

Stefan's law The total *energy* emitted in the form of *heat radiation* per unit time from unit area of a black body is proportional to the fourth power of its *absolute temperature* (see *black body radiation*). The constant of proportionality, Stefan's constant, $= 5.6697 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$. Also known as the Stefan-Boltzmann Law and constant. Named after Josef Stefan (1853-93). See Appendix, Table 2.

stellar evolution According to current views *stars* evolve during the course of their history. It is thought that they are born from *condensations* of *gas* (mostly hydrogen), which is compressed as a result of the *gravitational field* between the constituents. The compression is so great in the interior of the gas that *thermonuclear reactions* occur during which hydrogen is converted to helium (and

possibly heavier *elements*) with the evolution of *energy*. On a *Hertzprung-Russell diagram* the stars remain on the 'main sequence' until they have consumed some 10% of their hydrogen. They then become *red giants* and consume their hydrogen at increased rates so that eventually they contract and become *white dwarfs*. See also *novae*; *supernovae*.

Stellite* An alloy of cobalt (35%-80%), chromium (15%-40%), tungsten (10%-25%), molybdenum (0%-40%), and iron (0%-5%), that is hard and non-corroding; used for surgical instruments.

step-rocket See *rocket*.

steradian The supplementary *SI unit* of *solid angle*. The solid angle that encloses a surface on the *sphere* equal to the *square* of the radius. Symbol sr.

stere A metric unit of *volume*; 1 cubic *metre*.

stereochemistry *Chemistry* involving consideration of the arrangement in *space* of the *atoms* in a *molecule*. If a molecule is considered as a three-dimensional entity in space, possibilities of *stereoisomerism* or *space isomerism* arise; thus, a molecule consisting of four different *radicals* or *atoms* attached to a central carbon atom can exist in two distinct space arrangements, one being a *mirror image* of the other. Such isomerism is associated with *optical activity*.

stereoisomerism *Isomerism* caused by possibilities of different arrangement in three-dimensional space of the *atoms* within a *molecule*, resulting in two isomers that are mirror images of each other. See also *cis-trans isomerism*; *optical isomerism*; *stereochemistry*.

stereoregular Having a regular arrangement in space of the atoms and groups within a *molecule*. See *stereoregular rubbers*.

stereoregular rubbers A group of synthetic *rubbers* manufactured by a solution *polymerization* process using special *catalysts* that control the stereoisomeric (see *stereoisomerism*) regularity of the products. These materials can therefore be made to resemble closely the structure of natural rubber. In *cis-1,4-polyisoprene*, the structure of natural rubber is substantially duplicated, and this *elastomer* can be used for many of the purposes that were the exclusive preserve of natural rubber. A similar product is *cis-1,4-polybutadiene*, which is also used in place of natural rubber. See also *ethylene-propylene rubber*.

stereoscope An optical device by which two-dimensional pictures are given the appearance of depth and solidity.

stereospecific Having a particular arrangement in space of the atoms and groups within a *molecule*. See also *tactic polymer*.

steric hindrance (chem.) The hindering or retarding of a chemical reaction, as a result of the arrangement in space of the atoms of the reacting molecules.

steroids Derived *lipids* that include *sterols*, the *bile acids*, certain *hormones* and *glucosides*, and *vitamin D*.

STEROLS

sterols Derived *lipids* of the *steroid* group. *Cholesterol* and *ergosterol* are typical examples. Sterols are present in many living *organisms* in which they play an essential part.

stibine Antimony hydride. SbH_3 . A poisonous gas.

stibnite Natural *antimony trisulphide*, Sb_2S_3 . The principal ore of antimony.

stilbene *trans*-1,2-Diphenylethylene. Toluylene. $\text{C}_6\text{H}_5\text{CH}:\text{CHC}_6\text{H}_5$. A colourless *insoluble* substance, m.p. 124°C ., used in the manufacture of dyes.

stilboestrol $(\text{HO.C}_6\text{H}_4.\text{C.C}_2\text{H}_5)_2$. A white crystalline *organic compound*, m.p. 171°C ., used in medicine as an *oestrogen*.

still A *metal* or *glass* apparatus used for the *distillation* of *liquids*.

stimulated emission See *maser* and *laser*.

stochastic process A process that has some element of *probability* in its structure.

stoich(e)iometric A *compound* is said to be stoichiometric when its component *elements* are present in the exact proportions represented by its chemical *formula*. A stoichiometric *mixture* is one that will yield on reaction a stoichiometric compound (e.g. two *molecules* of hydrogen and one molecule of oxygen constitute a stoichiometric mixture because they yield exactly two molecules of *water* on *combustion*).

stoich(e)iometry The part of *chemistry* dealing with the composition of substances; more particularly with the determination of combining proportions or *chemical equivalents*.

stoke *C.g.s. system* unit of *kinematic viscosity* equal to the *viscosity* of a *fluid* in *poises* divided by the *density* in grams per cubic centimetres. 1 centistoke = 10^{-6} square *metre* per *second*. Named after Sir George Stokes (1819-1903).

Stokes' law A small *sphere* falling under the action of *gravity* through a *viscous* medium ultimately reaches a constant *velocity* equal to

$$v = 2gr^2(d_1 - d_2)/9\eta$$

where r = radius of the sphere, d_1 = *density* of the sphere, d_2 = *density* of the medium, and η = the coefficient of *viscosity* of the medium.

stopping power A measure of the ability of a substance to reduce the *kinetic energy* of a charged particle passing through it. The 'linear' stopping power is the energy lost per unit distance; the 'mass' stopping power is the linear stopping power divided by the *density* of the substance. Stopping power is often expressed relative to such standard substances as air or aluminium.

storage battery See *accumulator*.

storage ring A large evacuated *toroidal* ring forming part of some large particle *accelerators*. Particles from the accelerator are injected into the ring, around which they can be made to circulate for many

months. In some devices two beams of particles circulate in opposite directions. At the intersections of these two beams very high collision energies occur, enabling interactions to be studied. The 300 metre diameter ring at CERN, Geneva, enables energies up to 1700 GeV to be obtained.

store A part of the *hardware* of a *computer* in which information is stored. The 'random access' store is one in which the *access time* for any stored information is approximately the same. A 'high-speed' store is a random access store with an access time measured in *microseconds*. If this high speed is not required, *backing storage* is used.

S.T.P. See *standard temperature and pressure*.

straight chain A *hydrocarbon* molecule in which the carbon atoms are linked together in one long straight chain with no *side chains* attached.

strain (phys.) When a body is deformed by an applied *stress* the strain is the ratio of the dimensional change to the original or unstrained dimension. The strain may be a ratio of lengths, areas, or volumes.

strain gauge, electrical A grid of fine resistance wire supported on a paper base, which is attached by a suitable adhesive to the surface under test, so that any strains set up in the latter are accurately transferred to the gauge wire. The electrical *resistance* of the gauge is proportional to the *strain*, so that methods of measuring resistance may be used for measuring strain. The gauge is suitable for measuring strains of the order of 10^{-4} to 10^{-2} .

strain hardening Work hardening. An increase in the *hardness* and *tensile strength* of a *metal*, due to cold working, that causes a permanent alteration (distortion) of its crystalline structure.

strangeness Certain *hadrons* (*K-mesons* and *hyperons*) decay about 10^{12} times more slowly than would be expected from the large amounts of *energy* released in the processes. These particles, which are called strange particles, have been arbitrarily assigned a *quantum number*, *s*, to account for this strangeness. For ordinary particles (*nucleons*, *pions*, etc.) $s = 0$; each strange particle has a specific, *integral* value of *s*, which is not equal to 0. In the *quark* model, strange hadrons are postulated to contain the strange *s* quark (or its antiquark). Thus strangeness is one of the basic properties of matter. See Appendix, Table 6.

stratopause The boundary between the *stratosphere* and the *mesosphere*.

stratosphere A layer of the *atmosphere* beginning approximately 11 kilometres (7 miles) above the surface of the *Earth*. See Fig. 44, under *upper atmosphere*.

stratum A layer.

streamline A *streamline* is a line in a *fluid* such that the *tangent* to it at every point is in the direction of the *velocity* of the fluid particle at

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that point, at the instant under consideration. When the motion of the fluid is such that, at any instant, continuous streamlines can be drawn through the whole length of its course, the fluid is said to be in streamline flow.

streptomycin $C_{21}H_{39}N_7O_{12}$. An antibiotic substance produced by the *Streptomyces* fungus. It is effective against several types of disease bacteria, including some against which *penicillin* is inactive. Used in the treatment of tuberculosis.

stress (phys.) A force per unit area. When a stress is applied to a body (within its *elastic limit*) a corresponding *strain* is produced, and the ratio of stress to strain is a characteristic constant of the body. See *elastic modulus*.

stroboscope An instrument with the aid of which it is possible to view objects that are moving rapidly with a periodic motion (see *period*) and to see them as if they were at rest. For example, if a disc, rotating at n revolutions per second, is illuminated by a source flashing at the same *frequency*, then at any particular flash the eye will see the disc in exactly the same position as it was for the previous flash. The disc will therefore appear stationary. If the frequency of the motion is not quite equal to that of the flashing, the disc will appear to rotate slowly.

strong acid An *acid*, such as sulphuric acid, that is completely dissociated into *ions* in solution. Compare *weak acid*.

strong electrolytes See *electrolytic dissociation, theory of*.

strong interaction An interaction that occurs between *hadrons*. It occurs only at very short range (about 10^{-15} metre) and is the force that holds the *nucleons* together in an atomic *nucleus*. The strong interaction is some 100 times stronger than the *electromagnetic interaction* at this short range. The force between hadrons (sometimes called an *exchange force*) can be visualized as the exchange of virtual *mesons* between the particles (see *virtual state*).

strontia See *strontium oxide*. *Strontium hydroxide* is also sometimes known as strontia.

strontium Sr. Element. A.W. 87.62. At. No. 38. A reactive metal resembling calcium. R.d. 2.6, m.p. 757°C . It occurs as *celestine*, SrSO_4 , and *strontianite*, SrCO_3 . Compounds colour a flame crimson and it is used in fireworks. The *radioisotope* strontium-90 is present in the *fall-out* from nuclear explosions. It presents a health hazard as it has a relatively long *half-life* of 28 years and, owing to its chemical similarity to calcium, can become incorporated into bone. See *strontium unit*.

strontium hydroxide Strontia. $\text{Sr}(\text{OH})_2$. A white *deliquescent* crystalline powder, m.p. 375°C ., used in *sugar* refining as it combines with the *sugar* to form an *insoluble saccharate*.

strontium nitrate $\text{Sr}(\text{NO}_3)_2$. A colourless crystalline substance, m.p. 570°C ., used in fireworks and flares to give a bright crimson colour.

strontium oxide Strontia. SrO . A grey *amorphous* powder, m.p. 2430°C ., with similar properties to *calcium oxide*. Used in the manufacture of strontium *salts*.

strontium unit SU. A measure of the *concentration* of strontium-90 in an *organic* medium (e.g. milk, bone, soil, etc.) relative to the concentration of calcium in the same medium. $1 \text{ SU} = 10^{-12}$ curie of strontium-90 per gram of calcium.

structural formula A chemical *formula* that in addition to showing the *atoms* present in a *molecule*, also gives an indication of its structure. E.g. the structural formula of *benzene* (C_6H_6) is given by the *benzene ring*.

strychnine $\text{C}_{21}\text{H}_{22}\text{N}_2\text{O}_2$. An *alkaloid* that occurs in the seeds of *Strychnos nux vomica*. It is a white crystalline substance, slightly *soluble* in water; m.p. 284°C . It has an intensely bitter taste and a powerful and very dangerous action on the nervous system. Used in medicine in minute doses.

styrene Phenylethylene. $\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$. A colourless *aromatic liquid*, b.p. 146°C ., that polymerizes to a *thermoplastic* material (see *polystyrene*) and is used in the manufacture of synthetic *rubber*. See *styrene-butadiene rubber*.

styrene-butadiene rubber SBR. A widely used, general purpose synthetic *rubber*. A copolymer (see *polymerization*) of *butadiene* and about 35% of *styrene*, which is *vulcanized* in a similar manner to natural rubber. Properties are in general inferior to natural rubber, except for abrasion resistance, but passenger car tyres are made very largely from SBR. This *elastomer* is not suitable, however, for incorporation into heavy duty tyres.

sub- Prefix denoting under, below. In *chemistry* it is used to indicate either that the *element* mentioned is present in a lower proportion than usual, e.g. sub-oxide, or that the *compound* is *basic*, e.g. subacetate.

subatomic Consisting of particles smaller than, or forming a part of, the *atom*. See *atom*, *structure of*.

subcritical Said of a *nuclear reactor* in which the effective *multiplication constant* is less than unity, and in which the *nuclear chain reaction* is therefore not self-sustaining.

suberic acid $\text{HOOC}(\text{CH}_2)_6\text{COOH}$. A white crystalline *dibasic acid*, m.p. 140°C ., obtained from *castor oil* and used in the manufacture of *plastics* and *plasticizers*.

subgiant A *giant star* with a lower absolute *magnitude* than an ordinary giant.

sublate The product collected by ion *flotation*.

sublimate A *solid* obtained by the direct *condensation* of a vaporized solid without passing through the *liquid* state.

sublimation (chem.) The conversion of a *solid* direct into *vapour*, and subsequent *condensation*, without melting.

SUB-SHELL

- sub-shell** A concept used in the *Bohr theory* of atomic structure. Each electron *shell* is divided into sub-shells, for which all the electrons have the same azimuthal *quantum number*. The shells are designated by the letters *s, p, d, f*.
- subsonic** Moving at, or relating to, a *speed* that is less than Mach 1. See *Mach number*.
- substantive dyes** See *direct dyes*.
- substituent** See *substitution product*.
- substitution product** A *compound* obtained by replacing an *atom* or *group* by another *atom* or *group* in a *molecule*. The new *atom* or *group* is known as the 'substituent'.
- substrate** A substance whose reactivity is increased by a specific *enzyme*.
- subtend** (math.) Two points, *A* and *B*, are said to subtend the *angle ACB* at the point *C*.
- subtractive process** The process of producing *colours* by mixing three different dyes or pigments together. The final colour is produced by the absorption of different wavelengths of light. Compare *additive process*.
- succinate** A *salt* or *ester* of *succinic acid*.
- succinic acid** (CH_2COOH)₂. A white crystalline *organic dibasic acid*, m.p. 185°C. Used in the manufacture of *dyes*, *lacquers*, and other products.
- succinite** See *amber*.
- sucrase** See *invertase*.
- sucroclastic** *Sugar-splitting*; applied to *enzymes* that have the power of hydrolyzing complex *carbohydrates*. E.g. *invertase*.
- sucrose** Cane-sugar, beet sugar, saccharose. Common 'sugar' of the household. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A white sweet crystalline *disaccharide*, m.p. 160°-186°C. It is found in numerous plants, particularly the sugar cane, sugar beet, and maple tree sap.
- suction** This is not a positive *force* that 'draws' a *liquid* up; a liquid raised by so-called suction is actually pushed up by atmospheric *pressure*, which is greater than the pressure of the partial vacuum caused by the suction.
- sugar** In general, any sweet, *soluble*, *monosaccharide* or *disaccharide*. The word is commonly applied to *sucrose*.
- sugar of lead** See *lead acetate*.
- sulphanilic acid** $\text{NH}_2\text{C}_6\text{H}_4\text{SO}_3\text{H}\cdot\text{H}_2\text{O}$. A grey crystalline *soluble* substance, m.p. 288°C., used in the manufacture of *dyes*.
- sulphate** A *salt* or *ester* of *sulphuric acid*.
- sulphate of ammonia** See *ammonium sulphate*.
- sulphation** The formation of an insoluble layer of lead sulphate on the electrodes of a lead *accumulator*, when it is not in use and is left discharged for any length of time.

sulphide A binary compound of an element or group with sulphur; a salt of hydrogen sulphide, H_2S .

sulphite A salt or ester of sulphurous acid, H_2SO_3 .

sulpho The univalent radical HO.SO_2- .

sulphonamide drugs Sulpha drugs. A group of organic compounds, containing the sulphonamide group SO_2NH_2 or its derivatives; the group includes sulphanilamide ($\text{NH}_2\text{C}_6\text{H}_4\text{SO}_2\text{NH}_2$), sulphapyridine ($\text{NH}_2\text{C}_6\text{H}_4\text{SO}_2\text{NHC}_5\text{H}_4\text{N}$), sulphathiazole ($\text{NH}_2\text{C}_6\text{H}_4\text{SO}_2\text{NHC}_3\text{H}_2\text{NS}$), sulphadiazine ($\text{NH}_2\text{C}_6\text{H}_4\text{SO}_2\text{NHC}_4\text{H}_3\text{N}_2$), and many others. They are of great value in the treatment of many diseases caused by bacteria.

sulphonate A salt or ester of any sulphonic acid.

sulphones Organic compounds having the general formula $\text{R-SO}_2-\text{R}'$, where R and R' are organic radicals.

sulphonic acids Acids (usually organic) containing the sulpho group; e.g. benzenesulphonic acid.

sulphonyl The bivalent radical $-\text{SO}_2-$.

sulphur S. Element. A.W. 32.064. At. No. 16. A non-metallic element occurring in several allotropic forms. The stable form under ordinary conditions is rhombic or alpha-sulphur, a pale-yellow brittle crystalline solid, r.d. 2.07, m.p. 112.8°C ., b.p. 444.6°C . Sulphur burns with a blue flame to give sulphur dioxide; it combines with many metals to form sulphides. Sulphur occurs as the element in many volcanic regions and as sulphides of many metals. It is extracted in vast quantities in Texas by the Frasch process. Used in the manufacture of sulphuric acid, carbon disulphide, for vulcanizing rubber, in the manufacture of dyes and various chemicals, for killing moulds and pests, and in medicine.

sulphur dioxide SO_2 . A colourless gas with a choking penetrating smell; liquid SO_2 is used in bleaching, fumigating, and as a refrigerant.

sulphur dyes Dyes made by heating certain organic substances with sulphur and sulphides. They are usually of polymeric nature, and are insoluble in water, but when heated with sodium sulphide the large molecules break down to form a water-soluble leuco compound (see vat dyes), which dyes cellulosic fibres. The final dyeing is obtained by oxidation, as in the case of vat dyes. These dyes are very cheap but give dull hues; they are widely used for dyeing industrial fabrics.

sulphuretted hydrogen See hydrogen sulphide.

sulphuric acid Vitriol, oil of vitriol. A colourless oily liquid dibasic acid, r.d. 1.84. It is extremely corrosive, reacts violently with water with evolution of heat, and chars organic matter. It is prepared by the contact process (and formerly by the lead-chamber process). Used extensively in many processes in chemical industry, and in the lead accumulator.

SULPHURIC ACID, FUMING

sulphuric acid, fuming See *oleum*.

sulphuric anhydride See *sulphur trioxide*.

sulphuric ether An obsolete name for diethyl ether. See *ethers*.

sulphurous acid H_2SO_3 . A colourless *liquid* formed when *sulphur dioxide* dissolves in *water*. Used in the form of its salts, the *sulphites*.

sulphur point The *temperature* of equilibrium between *liquid sulphur* and its *vapour* at a *pressure* of one standard atmosphere; 444.6°C .

sulphur trioxide Sulphuric anhydride. SO_3 . A white crystalline *solid*, m.p. 16.8°C ., that combines with *water* to form *sulphuric acid*.

sulphuryl The *bivalent radical* $-\text{SO}_2-$ in an *inorganic compound*.

sulphuryl chloride SO_2Cl_2 . A colourless *liquid*, b.p. 69.1°C ., used as a chlorinating agent.

Sun The incandescent, approximately spherical heavenly body around which the *planets* rotate in elliptical *orbits* (see *solar system*). The Sun is a 'main sequence' *star* (see *Hertzprung-Russell diagram*), being one of some 10^{11} stars that constitute our *Galaxy*. Mean distance from the *Earth* is approximately 149.6×10^6 kilometres, and the distance to nearest star is approximately 40×10^{12} km. The diameter of the Sun is about 1 392 000 km, its *mass* is approximately 2×10^{30} kilograms, and its average *density* 1.4 grams per cm^3 . The visible surface of the Sun, called the *photosphere*, is at a *temperature* of about 6000°C .; its interior temperature is some $13\,000\,000^\circ\text{C}$. At this internal temperature *thermonuclear reactions* occur in which hydrogen is converted into helium, these reactions providing the Sun with its vast supply of *energy*. The Sun is composed of about 90% hydrogen, 8% helium, and only 2% of the heavier *elements*.

sunspots Large patches, which appear black by contrast with their surroundings, visible upon the surface of the *Sun*. Owing to the rotation of the Sun, they appear to move across its surface. Their appearance is spasmodic, but their number reaches a maximum approximately every eleven years. (See *eleven year period*.) They are connected with such phenomena as magnetic storms and the *aurora borealis*. See *solar flares*; *solar prominences*; *solar wind*.

super- Prefix denoting over, above.

superconductivity The electrical *resistance* of a *metal* or *alloy* is a function of *temperature*, decreasing as the temperature falls and tending to zero at the *absolute zero*. It is found that for certain metals and alloys (e.g. lead, vanadium, tin) the resistance changes abruptly, becoming vanishingly small at a temperature in the neighbourhood of a few degrees above absolute zero. This phenomenon is termed superconductivity, and the temperature at which it sets in is the transition temperature. A current induced by a *magnetic field* in a ring of superconducting material will continue to circulate after the magnetic field has been removed. (See also *cryotron*.) This effect has been used to produce large magnetic fields

without the expenditure of appreciable quantities of *electrical energy* (except in maintaining the very low temperature).

supercooling The *metastable* state of a *liquid* cooled below its *freezing point*. A supercooled liquid will usually freeze on the addition of a small particle of the *solid* substance, and often on the addition of any solid particle or even on shaking; the *temperature* then rises to the freezing point.

supercritical Said of a *nuclear reactor* in which the effective *multiplication factor* exceeds unity, and in which the nuclear *chain reaction* is therefore self-sustaining.

superdense theory Big-bang theory. The theory in *cosmology* that the *Universe* has evolved from one 'superdense' agglomeration of *matter* that suffered a cataclysmic explosion. The observed *expansion of the Universe* is regarded as a result of this explosion, the *galaxies* flying apart like fragments from an exploding bomb. This hypothesis, which presupposes a finite beginning and probably a finite end to the history of the Universe, is in opposition to the *steady state theory*. At present the evidence, such as it is, appears to favour the superdense theory.

superfluid A *fluid* that flows without *friction* and has an abnormally high thermal *conductivity*, e.g. helium below 2.186 K.

supergiant star A *star* of exceptionally high *luminosity*, low *density*, and a diameter some hundreds of times greater than the *Sun*.

superheated steam *Steam* above a *temperature* of 100°C., which is obtained by heating *water* under a *pressure* greater than atmospheric.

superheating Heating a *liquid* above its *boiling point*, when the liquid is in a *metastable* state. See *supercooling*.

superheterodyne Superhet. Abbreviation of 'supersonic heterodyne'. A method of *radio* reception in which the *frequency* of the *carrier wave* is changed in the receiver to a 'supersonic' *intermediate frequency* (i.e. a frequency above the audible limit for *sound*) by a *heterodyne* process.

super high frequency S.H.F. *Radio frequencies* in the range 3000 to 30 000 *megahertz*.

supernovae *Stars* that suffer an explosion becoming some 10^8 times brighter than the *Sun* during the process. They are relatively rare events, only two having been recorded within our *Galaxy*, although they have been observed fairly regularly in other *galaxies*. These explosions are believed to be caused when a star runs out of hydrogen and contracts under its own *gravitational field*. The contraction causes a sufficiently high *temperature* in the interior for *thermonuclear reactions* to occur, which produce heavy *elements*. The formation of heavy elements, with *atomic numbers* in excess of about 40, absorbs *energy* and the star collapses inwards, increasing its speed of rotation and ultimately flinging a large portion of its *matter* into *space*. It is believed that the *planets* of the *solar system*

SUPERPHOSPHATE

consist of matter thrown into space by a supernova, which was subsequently collected by the Sun's gravitational field. The residue of a supernova explosion is a *white dwarf* star.

superphosphate An artificial *fertilizer* consisting mainly of calcium hydrogen orthophosphate. See *calcium phosphate*.

superplasticity The property, exhibited by certain metallic *alloys*, of stretching several hundred per cent before failing, e.g. zinc in aluminium.

supersaturation The *metastable* state of a *solution* holding more dissolved *solute* than is required to *saturate* the solution.

supersonic Moving at, or relating to, a *speed* in excess of Mach 1. See *Mach number*.

supersonics See *ultrasonics*.

supplementary angles *Angles* together totalling 180° , or two right angles.

suppressor grid A grid, placed between the *screen grid* and the *anode* of a *thermionic valve*, to reduce the *secondary emission* of *electrons* between them.

surd An irrational quantity; a *root* that cannot be expressed as an exact number or fraction; e.g. $\sqrt{2}$.

surface-active agent Surfactant. A substance introduced into a *liquid* in order to affect (usually to increase) its spreading, wetting, and similar properties (i.e. properties which depend upon its *surface tension*). Many *detergents* fall into this class.

surface colour Certain reflecting surfaces, e.g. *metal* surfaces, exhibit selective reflection of *light* waves; i.e. they reflect some *wavelengths* (*colours*) more readily than others. When illuminated by *white light*, such surfaces reflect light deficient in certain wavelengths, and the body appears coloured. The body is then said to show surface colour, as opposed to *pigment colour*. Bodies showing surface colour when viewed by transmitted light appear to be of the *complementary colour* to that observed when viewed by reflected light. Substances that show pigment colour appear the same colour whether viewed by reflected or transmitted light.

surface tension γ . An open surface of a *liquid* is under a state of tension, causing a tendency for the portions of the surface to separate from each other; the surface thus shows properties similar to those of a stretched elastic film over the liquid. The tension is an effect of the *forces* of attraction existing between the *molecules* of a liquid. Measured by the force per unit length (*newtons per metre*) acting in the surface at right angles to an element of any line drawn in the surface. A surface tension exists in any boundary surface of a liquid.

surfactant See *surface-active agent*.

susceptance *B*. The imaginary part of the *admittance* of a circuit. It is the reciprocal of the *reactance* and is measured in *siemens*.

susceptibility, magnetic See *magnetic susceptibility*.

suspension (chem.) A two-phase system (see *phase*) consisting of very small *solid* particles distributed in a *liquid dispersion medium*.

suspenoid sol See *colloidal solutions*.

sylvine Natural *potassium chloride*, KCl, usually containing *sodium chloride* as an impurity. An important source of potassium compounds.

symbiosis A relationship between two different types of *organism* that live together for their mutual benefit. E.g. the relationship between *cellulose-digesting bacteria* and the herbivores whose alimentary tract they inhabit.

symbol (chem.) A letter or letters representing an *atom* of an *element*; e.g. S = one atom of sulphur. Often loosely taken to mean the element in general, e.g. Fe = iron. See *formula*. The symbols of all the elements are given in Table 3 of the Appendix.

symmetry The correspondence of parts of a figure with reference to a *plane*, line, or point of symmetry. Thus, a *circle* is symmetrical about any diameter; a *sphere* is symmetrical about a plane of any great circle.

synapse A junction between *neurones* by which nerve impulses are transferred within the nervous systems of animals. A synapse is usually formed between the *axon* of one neurone and the cell body or *dendrite* of another.

synchrocyclotron A type of *cyclotron* that enables *relativistic velocities* to be achieved by modulating the *frequency* of the accelerating *electric field*.

synchronous motor An *alternating current electric motor* whose speed of rotation is proportional to the *frequency* of its power supply.

synchronous orbit Stationary orbit. The *orbit* of an artificial Earth *satellite* that has a *period* of 24 hours. The altitude corresponding to such an orbit is about 35 700 km; a satellite in a circular orbit parallel to the *equator* at this altitude would appear to be stationary in the sky. Communication satellites in synchronous orbits are used for relaying *radio* signals between widely separated points on the Earth's surface.

synchrotron An *accelerator* of the *cyclotron* type in which the *magnetic field* is modulated but the *electric field* is maintained at a constant *frequency*.

synchrotron radiation High energy *electrons* within a *synchrotron* emit *light* as a consequence of their *acceleration* in a strong *magnetic field*; this emission is known as synchrotron radiation. The term is also used to describe the emission of *radio frequency electromagnetic radiations* from interstellar gas clouds in *radio galaxies* (see *radio astronomy*) as this emission is believed to be an analogous phenomenon.

SYNDIOTACTIC POLYMER

syndiotactic polymer See *atactic polymer*.

syneresis The separation of *liquid* from a *gel*.

synodic month See *lunation*.

synodic period of a planet The period between two successive *conjunctions* with the *Sun*, as observed from the *Earth*.

synthesis (chem.) 'Putting together'; the formation of a *compound* from its *elements* or simpler compounds.

synthetic (chem.) Artificially prepared from the component *elements* or simpler materials; not obtained directly from natural sources.

Système International d'Unités See *SI units*.

syzygy A point of *opposition* or *conjunction* of a *planet*, or the *Moon*, with the *Sun*.

T

- tachometer** An instrument for measuring the rate of revolution of a revolving shaft.
- tachyon** A hypothetical particle that travels faster than the *velocity of light*. To satisfy the *special theory of relativity* such a particle would have imaginary *energy* and *momentum* if it had a real *rest mass*, or imaginary rest mass if the energy was real. Its presence could be detected by the *Cerenkov radiation* it emits, but no such particle has yet been detected.
- tacnode** A point at which two branches of a curve touch each other and have a common *tangent*.
- tactic polymer** A *polymer* in which the groups attached to the polymer chain are regularly arranged, giving a *stereospecific* and a *stereoregular* structure. Compare *atactic polymer*.
- talc** Hydrated magnesium silicate, $3\text{MgO} \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$. Used as a lubricant and in talcum powder.
- tall oil** A resinous substance obtained as a *by-product* in the manufacture of wood-pulp, used in *soaps* and *paints*.
- tallow** The rendered fat of animals, particularly cattle and sheep. It consists of various *glycerides*.
- tandem generator** An *accelerator* of the *electrostatic generator* type. The name is derived from the fact that it consists essentially of two *Van der Graaff generators* in series, thus enabling twice as much *energy* to be obtained for a given accelerating *potential* as could be obtained from a single machine. Negative *ions* are accelerated from ground potential, the *electrons* are then 'stripped' off and the positive particles accelerated back to ground potential.
- tangent galvanometer** A *galvanometer* consisting of a coil of wire (n turns of radius r) held in a vertical plane parallel to the Earth's *magnetic field*, H , with a small magnetic needle pivoted at the centre of the coil that is free to rotate in a horizontal plane. A direct *electric current*, I , flowing through the coil produces a magnetic field at right angles to that of the Earth. The needle takes up the direction of the *resultant* of these two fields: if θ is the *angle* of deflection of the needle from its equilibrium position parallel to the Earth's field, then the current will be given by: $I = Hr \tan \theta / 2\pi n$.
- tangent of an angle** See *trigonometrical ratios*.
- tangent to a curve** A straight line touching the curve at a point. The tangent to a *circle* at any point is at right angles to the radius of the circle at that point.
- tannic acid** A white amorphous solid, extracted from gall-nuts; it is a

TANNING

polymeric ester-type derivative of *gallic acid* and *glucose*. Used in tanning, as a *mordant* in dyeing, and in ink manufacture.

tanning The conversion of raw animal hide into leather by the action of substances containing *tannin*, *tannic acid*, or other agents.

tannins A class of complex *organic compounds* of vegetable origin. Compounds consist of *mixtures* of *derivatives* of polyhydroxy *benzoic acids*; e.g. *tannic acid*.

tantalum Ta. Element. A.W. 180.948. At. No. 73. A greyish-white *metal* that is very ductile and malleable. R.d. 16.6, m.p. 2996°C. It occurs together with niobium in a few rare *minerals* and is extracted by *reduction* of the *oxide* with carbon in an *electric furnace*. Used for electric lamp *filaments*, in *alloys*, in cemented *carbides* for very hard tools, and in electrolytic *rectifiers*.

tape recording See *magnetic tape*.

tar Various dark, viscous *organic materials*; e.g. *coal-tar*.

tartar See *argol*.

tartar emetic See *antimony potassium tartrate*.

tartaric acid $\text{COOH}(\text{CH}_2\text{OH})_2\text{COOH}$. An *organic acid* existing in four stereoisomeric forms (see *stereoisomerism*). The common form, *d*-tartaric acid, obtained from *argol*, is a white *soluble crystalline solid*, m.p. 170°C. Used in dyeing, calico-printing, and in making *baking-powder* and effervescent 'health salts'. *dl*-tartaric acid (*racemic acid*), m.p. 203–4°C., occurs in grapes.

tartrate A salt or ester of *tartaric acid*.

tau particle A heavy *lepton* that reacts by the *weak interaction*. It has a very short lifetime (about 5×10^{-12} second) and a mass of approximately 1800 MeV (i.e. about 3500 times heavier than an electron). There is strong evidence for its existence.

taurine $\text{NH}_2(\text{CH}_2)_2\text{SO}_3\text{H}$. A white crystalline substance, m.p. 328°C., obtained from the *bile* of mammals.

tautomerism Dynamic isomerism. The existence of a *compound* as a mixture of two *isomers* in equilibrium. The two forms are convertible one into the other, and removal of one of the forms from the *mixture* results in the conversion of part of the other to restore the equilibrium; but each of the two forms may give rise to a stable series of *derivatives*. A substance exhibiting this property is called a 'tautomer'. See also *keto-enol tautomerism*.

tear gases Lachrymators. Substances that can be distributed in the form of a *vapour* or *smoke*, producing an irritating effect on the eyes.

technetium Masurium. Te. Element. At. No. 43. The most stable *isotope*, $^{97}_{43}\text{Te}$, has a *half-life* of 2.6×10^6 years. It is not found in nature but formed as a *fission product* of uranium.

Teflon* See *tetrafluoroethylene* and *fluorocarbons*.

tektites Small glass-like bodies whose chemical composition is unrelated to the geological formations in which they are found: they are

believed to be associated with *meteorites* of extra-terrestrial origin. Carbonaceous' tektites contain traces of carbon *compounds*.

telecommunications The telegraphic or telephonic communication of signals, images, or sounds by line or *radio* transmission.

telegraph A method of transmitting messages over a distance by means of electrical impulses sent through wires. By depressing a key at the transmitting end, a circuit is closed and an *electric current* flows through the conducting wire or cable to the receiver; the dots and dashes of the Morse code being obtained by varying the length of time for which the current flows. At the receiving end, the feeble electrical impulses are made to operate a *relay*, which then closes a local circuit, carrying a larger current. This current either sounds a *buzzer*, or a *telephone* receiver, or causes the dots and dashes to be automatically recorded.

telemeter Any apparatus for recording a physical event at a distance. E.g. an instrument in an artificial *satellite* that transmits measurements made in *space* back to *Earth* by *radio*.

telephone The circuit, which is closed when the line is connected, consists essentially of a transmitter and a receiver connected by an electrical *conductor*. The transmitter is usually a carbon *microphone*, by means of which variable electrical impulses, depending on the nature of the *sounds* made into the microphone, are caused to flow through the circuit. In the telephone receiver these impulses flow through a pair of coils of wire wound upon soft iron pole-pieces attached to the poles of a *magnet*; an iron diaphragm near these coils experiences variable pulls, and thus vibrates so as to produce sounds corresponding to those made into the microphone.

telephoto lens A combination of a *convex* and a *concave lens*, used to replace the ordinary lens of a *camera* in order to magnify the normal image. The size of the image obtained on the photographic *film* varies as the *focal length* of the lens. The telephoto lens system increases the effective focal length without the necessity of increasing the distance between the film and the lens.

telescope A device for viewing magnified images of distant objects. In the refracting telescope the *objective* is a large *convex lens* that produces a small, bright, real *image*; this is viewed through the *eye-piece*, which is another convex lens, serving to magnify the image. In the reflecting telescope a large *concave mirror* (see *speculum*) is used instead of the objective lens to produce the real image, which is then magnified by the eye-piece. For terrestrial needs, these types of telescope are unsuitable, since the images formed are inverted; for terrestrial purposes telescopes are equipped with a further lens or *prism* that causes the image to be seen erect. See also *Cassegranian*, *Galilean*, *Gregorian*, *Herschelian*, *Maksutov*, *Newtonian*, *Schmidt*, and *radio telescopes*.

TELETYPE*

Teletype* Tradename for a *computer terminal* consisting of a device resembling a typewriter that can be combined with a paper-tape reader and punch.

television The transmission of visible, moving images by electrical means. In 'closed circuit' television the transmission is by line; in 'broadcast' television it is by *radio* waves. In either case *light* waves are converted into electrical impulses by a television *camera* and reconverted into a picture on the screen of a *cathode-ray tube* in the receiver. In broadcast television the transmitter consists of equipment for broadcasting modulated *radio frequency electromagnetic radiations* representing a complete television signal, which includes *sound*, vision, and synchronizing signals. The receiver is based on the *superheterodyne* principle, the sound and vision signals being fed to separate *intermediate frequency* amplifiers, *detectors*, and output stages.

telluric 1. Pertaining to the *Earth* (as a *planet*), or the earth or *soil*.
2. Derived from or containing *hexavalent tellurium*.

tellurium Te. Element. A.W. 127.6. At. No. 52. A silvery-white brittle non-metal, resembling sulphur in its chemical properties. R.d. 6.24, m.p. 452°C. It exists in several *allotropic forms*. Used in *alloys*, for colouring *glass*, and in *semiconductors*.

tellurous Containing *tetravalent tellurium*.

temperature The temperature of a body is a measure of its 'hotness', which can be defined as a property determining the rate at which *heat* will be transferred to or from it. Temperature is thus a measure of the *kinetic energy* of the *molecules*, *atoms*, or *ions* of which *matter* is composed. The basic physical quantity, the *thermodynamic temperature*, is expressed in *kelvins*. These units are also used in the *International Practical Temperature Scale*. Other scales of temperature are the *Celsius* (*Centigrade*), *Fahrenheit*, and *Réaumur scales*.

tempering of steel Imparting a definite degree of hardness to *steel* by heating to a definite *temperature* (which is sometimes determined by the *colour* the steel assumes) and then *quenching*, i.e. cooling, in *oil* or *water*.

temporary hardness of water Hardness of *water* that is destroyed by *boiling*. See *hard water*.

temporary magnetism Induced magnetism. *Magnetism* that a body (e.g. soft iron) possesses only by virtue of being in a *magnetic field* and that largely disappears on removing the body from the field.

tenorite A naturally occurring oxide of copper that consists of small black scales. It is found in volcanic regions and in copper veins.

tensile strength Tenacity. The tensile (pulling) *stress* that has to be applied to a material to break it. It is measured as a *force* per unit area; e.g. *newtons* per square *metre*; *dynes* per square centimetre; pounds or tons per square inch.

tensimeter An instrument for measuring vapour pressure.

tensiometer 1. An apparatus for measuring the *surface tension* of a liquid. 2. An apparatus for measuring the tension in a wire, fibre, or beam. 3. An apparatus for measuring the moisture content of soil.

tensor A magnitude or set of *functions* by which the components of a system are transformed from one system of *coordinates* to another: a quantity expressing the ratio in which the length of a vector is increased.

terbium Tb. Element. A.W. 158.924. At. No. 65. R.d. 8.25, m.p. 1356°C. See *lanthanides*.

terephthalic acid 1,4-Benzenedicarboxylic acid. $C_6H_4(COOH)_2$. A white insoluble crystalline substance, the *para-isomer* of phthalic acid, that sublimes (see *sublimation*) without melting above 300°C. Used in the manufacture of *polyesters*, in particular, *polyethylene terephthalate*.

terminal 1. (phys.) The point at which an electrical connection is made; the point, or the connecting device, at which *current* enters or leaves a piece of electric equipment. 2. An input or output device connected to a *computer*; it may be a *line printer*, a punched-card reader, a *Teletype*, or a *visual-display unit*.

terminal velocity If a body free to move in a resisting medium is acted upon by a constant force (e.g. a body falling under the force of *gravity* through the atmosphere), the body accelerates until a certain terminal velocity is reached, after which the *velocity* remains constant. See *Stokes' Law*.

terminator The line on the surface of the *Moon*, or a *planet*, that separates the dark and light hemispheres.

termolecular reaction A *chemical reaction* in which there are three *reactant molecules*. E.g. $2H_2 + O_2 = 2H_2O$.

ternary compound A chemical compound consisting of three *elements*. E.g. HNO_3 (*nitric acid*).

ternary fission A very rare form of *nuclear fission* as a result of which a heavy *nucleus* breaks up into three fragments of comparable *mass*. The term is also used for the more frequent case in which one of the three fragments (e.g. an *alpha-particle*) is much lighter than the others.

terpenes A class of *hydrocarbons* occurring in many fragrant *essential oils* of plants. They are colourless *liquids*, generally with a pleasant smell. Terpenes include *pinene*, $C_{10}H_{16}$, the chief ingredient of *turpentine*; and *limonene*, $C_{10}H_{16}$, found in the essential oils of oranges and lemons.

terpineol $C_{10}H_{17}OH$. Several *isomeric unsaturated alcohols* that occur in *essential oils*. α -terpineol, m.p. 35°C., b.p. 220°C., is used as a *solvent* and in perfumes.

Terramycin* Oxytetracycline. $C_{22}H_{30}N_2O_{11}$. An *antibiotic powder*

TERRESTRIAL GUIDANCE

- obtained from *Streptomyces rimosus* bacteria, used to combat streptococci and staphylococci infections.
- terrestrial guidance** A method of missile or *rocket* guidance in which the missile steers itself with reference to the strength and direction of the *Earth's gravitational or magnetic field* (magnetic guidance).
- terrestrial magnetism** See *magnetism, terrestrial*.
- terrestrial telescope** A *telescope* for use on land or sea, as opposed to an astronomical telescope.
- tertiary colour** A *colour* obtained by mixing two *secondary colours*.
E.g. brown and grey.
- trivalent** Trivalent. Having a *valence* of three.
- Terylene*** See *polyethylene terephthalate*.
- tesla** The derived *SI unit* of *magnetic flux density*, defined as the density of one *weber* of *magnetic flux* per square *metre*. Symbol *T*. Named after Nikola Tesla (1870-1943).
- Tesla coil** A *transformer* for producing high *voltages* at high *frequencies*, consisting of a coil the primary circuit of which has a small number of turns but includes a spark gap and a fixed *capacitor*. The secondary winding has a large number of turns and the secondary circuit is *tuned*, by means of a variable capacitor, to resonate with the primary.
- testosterone** $C_{19}H_{28}O_2$. A male sex *hormone* (*androgen*), which in the pure form consists of a white *insoluble* crystalline substance, m.p. $155^{\circ}C.$, whose function is to promote the development of male characteristics.
- tetra-** Prefix denoting one million million; 10^{12} . Symbol *T*.
- tetra-** Prefix denoting four, fourfold.
- tetrachloroethylene** Perchloroethylene. $Cl_2C:CCl_2$. A colourless non-inflammable *liquid*, b.p. $121^{\circ}C.$, used as a *solvent* and in dry cleaning.
- tetrad** An *element* having a *valence* of four.
- tetraethyl-lead** $(C_2H_5)_4Pb$. A colourless oily *liquid*, used as an anti-knocking compound in *petrol*.
- tetraethyl pyrophosphate** T.E.P.P. $(C_2H_5)_4P_2O_7$. A colourless *hygroscopic liquid*, b.p. $155^{\circ}C.$, used as an *insecticide* and rat poison.
- tetrafluoroethylene** $CF_2:CF_2$. An unsaturated gaseous fluorocarbon, b.p. $-76.3^{\circ}C.$, that polymerizes (see *polymerization*) into a *thermoplastic* material with good electrical insulation properties (trade names Teflon*, and Fluon*. See *polytetrafluoroethylene*).
- tetrahedron** A four-faced, *solid* figure, contained by four *triangles*; a *pyramid* with a triangular base.
- tetranitromethane** $C(NO_2)_4$. A colourless *volatile liquid*, b.p. $126^{\circ}C.$, used as an *oxidant* in *rockets*.
- tetravalent** Quadrivalent. Having a *valence* of four.
- tetrode** A *thermionic valve* containing four *electrodes*; a *cathode*, an

anode or plate, a *control grid*, and (between the two latter) a *screen grid*.

thalidomide $C_{13}H_{10}N_2O_4$. A white crystalline substance, formerly used as a *tranquillizer* but found to be the cause of deformed children when taken by pregnant women.

thallic Containing *trivalent* thallium.

thallium Tl. Element. A.W. 204.37. At. No. 81. A white malleable *metal* resembling lead. R.d. 11.85, m.p. 303.5°C. Used in *alloys*; its salts are used in *insecticides* and rat poisons.

thallous Containing *univalent* thallium.

thebaine $C_{19}H_{21}NO_3$. A white *insoluble* substance, m.p. 193°C., present in *opium* in small quantities.

theine See *caffeine*.

theobromine $C_7H_8N_4O_2$. A white *insoluble* crystalline *alkaloid*, m.p. 337°C., that is *isomeric* with 'theophylline', m.p. 272°C. Both occur in tea and are used in medicine.

theodolite An instrument for the measurement of *angles*, used in surveying. It consists essentially of a *telescope* moving along a circular scale graduated in *degrees*.

theophylline See *theobromine*.

theorem A statement or proposition that is proved by logical reasoning from given facts and justifiable assumptions.

theory of games A mathematical treatment of competitive games with special reference to the strategic and tactical decisions that have to be made in situations involving conflicting interests in the light of specific odds and *probabilities*. The theory is extended for use in military and commercial situations.

therapeutics Healing; remedial treatment of diseases.

therm A practical unit of quantity of *heat*; 100 000 *British thermal units*, 25 200 000 *calories*, $1.055\ 06 \times 10^8$ *joules*.

thermal analysis See *thermographic analysis*.

thermal barrier The limit to the *speed* with which an aircraft or *rocket* can travel in the Earth's *atmosphere* due to overheating caused by *friction* with the atmospheric *molecules*.

thermal capacity See *heat capacity*.

thermal cross-section A nuclear *cross-section* as measured with *thermal neutrons*.

thermal diffusion If a *temperature* gradient is maintained over a *volume* of gas containing *molecules* of different *masses*, the heavier molecules tend to diffuse down the temperature gradient, and the lighter molecules in the opposite direction. This forms the basis of a method of separating the different *isotopes* of an *element* in certain cases.

thermal dissociation See *dissociation*.

thermal equilibrium The state of a system in which there is no net flow of *heat* between its components.

THERMALIZE

thermalize To bring *neutrons* into *thermal equilibrium* with their surroundings; to reduce the *energy* of neutrons with a *moderator*; to produce *thermal neutrons*.

thermal neutrons *Neutrons* of very slow speed and consequently of low *energy*. Their energy is of the same order as the thermal energy of the *atoms* or *molecules* of the substance through which they are passing, i.e. about 0.025 *electron-volt*, which is equivalent to an average *velocity* of about 2200 metres per second. Thermal neutrons are responsible for numerous types of *nuclear reactions*, including *nuclear fission*.

thermal reactor A *nuclear reactor* in which most of the *nuclear fissions* are caused by *thermal neutrons*.

thermal spike The zone of high *temperature* briefly produced in a substance along the path of a high energy particle or *nuclear fission* fragment.

thermion An *ion* emitted by a hot body.

thermionic emission The emission of *electrons* from a heated *metal*, especially in *thermionic valves*.

thermionics The branch of *electronics* dealing with the emission of *electrons* from substances under the action of *heat*, particularly the study and design of *thermionic valves*.

thermionic valve or tube A system of *electrodes* arranged in an evacuated *glass* or *metal* envelope. For special purposes a *gas* at low *pressure* may be introduced into the valve. The electrodes are: (1) a *cathode* that emits *electrons* when heated; (2) an *anode* or plate maintained at a positive *potential* with respect to the cathode; the electrons emitted by the latter are attracted to it. Most valves also contain a number of perforated electrodes or grids (see *control grid*, *screen grid*, *suppressor grid*) interposed between the cathode and anode, designed to control the flow of current through the valve. The cathode can be in the form of a *filament* heated by an *electric current* passing through it, or an electrode heated indirectly by a separate filament. See *diode*; *triode*; *tetrode*; *pentode*.

thermistor A *semiconductor*, the electrical *resistance* of which decreases rapidly with increase of *temperature*; e.g. the resistance may be of the order of 10^5 ohms at 20°C. and only 10 ohms at 100°C. Used as a sensitive temperature-measuring device and to compensate for temperature variations of other components in a circuit.

thermite Thermit*. A *mixture* of aluminium powder and the *oxide* of a *metal*, e.g. *ferric oxide*. When ignited by magnesium ribbon, a *chemical reaction* begins in which the aluminium combines with the oxygen of the oxide, forming *aluminium oxide* and the metal. A great quantity of *heat* is given out during the reaction, the reduced metal (see *reduction*) appearing in the molten state. The mixture is used for *welding* iron and *steel*, and in incendiary bombs; the

principle is applied in the extraction of certain metals from their oxides (see *Goldschmidt process*).

thermobarograph An instrument for measuring and recording atmospheric temperature and pressure, consisting of a *thermograph* and a *barograph*.

thermochemistry The branch of *physical chemistry* dealing with the quantities of heat absorbed or evolved during *chemical reactions*. See *heat of reaction*; *Hess's law*.

thermocouple An instrument for the measurement of temperature. It consists of two wires of different metals joined at each end. One junction is at the point where the temperature is to be measured and the other is kept at a lower fixed temperature. Owing to this difference of temperature of the junctions, a thermoelectric E.M.F. is generated, causing an electric current to flow in the circuit (see *Seebeck effect*). This current can be measured by means of a *galvanometer* in the circuit, or the thermoelectric E.M.F. can be measured using a *potentiometer*.

thermodynamic energy *U*. See *internal energy*.

thermodynamics The study of the general laws governing processes that involve heat changes and the conservation of energy.

thermodynamics, laws of 1. The law of the conservation of energy. In a system of constant mass, energy can be neither created nor destroyed. A special case of this general law is the principle of the *mechanical equivalent of heat*. 2. Heat cannot be transferred by any continuous, self-sustaining process from a colder to a hotter body. Or stated in terms of *entropy*; the entropy of a closed system increases with time. 3. See the *Nernst heat theorem*. The consequence of this law is that the *absolute zero* of temperature can never be attained.

thermodynamic temperature *T*. Although formerly referred to as a scale of temperature (Kelvin scale of temperature, or absolute scale of temperature), the concept of a temperature scale is now restricted to the *International Practical Temperature Scale of 1968*. The thermodynamic temperature is a basic physical quantity that depends on the concept of temperature as a measure of the thermal energy of random motion of the particles of a system in *thermal equilibrium*. Originally, thermodynamic temperature was defined in terms of the *ice point* and *steam point* of water using a *gas thermometer*. However, in 1954 this was replaced by a definition using only one fixed point, the *triple point* of water, which was fixed as 273.16 *kelvins* exactly. The magnitude of the unit of thermodynamic temperature, the *kelvin*, is the same as the *degree* on the *International Practical Scale of Temperature*.

thermoelectric effect See *Seebeck effect*.

thermoelectricity Electricity produced by the direct conversion of heat

THERMOGRAPH

energy into *electrical energy*. See *thermocouple*; *Thomson effect*; *Seebeck effect*.

thermograph A self-registering *thermometer*; an apparatus that records *temperature* variations during a period of time on a *graph*.

thermographic analysis A group of methods of chemical analysis based on recording changes of mass (*thermogravimetric analysis*) due to decomposition, or of temperature ("heating curves") due to *endothermic* or *exothermic* processes, when substances that undergo chemical changes on heating are heated at a definite rate.

thermoluminescence *Luminescence* resulting from the application of heat to a body or substance. It occurs when *electrons*, trapped in crystal defects, are freed by heating the crystals.

As these defects are usually caused by *ionizing radiation*, the property is used as a method of dating archaeological remains, especially pottery. The number of trapped electrons can be assumed to be related to the quantity of radiation to which the pottery has been subjected since it was fired. By assuming that this quantity is related to its age an estimate of age can be obtained by measuring the amount of light emitted by the pottery on heating.

thermometer An instrument for the measurement of *temperature*. Any physical property of a substance that varies with temperature can be used to measure the latter; e.g. the *volume* of a *liquid* or *gas* maintained under a fixed *pressure*; the pressure of a gas at constant volume; the electrical *resistance* of a *conductor*; the *E.M.F.* produced at a *thermocouple* junction, etc. The property chosen depends on the temperature range, the accuracy required, and the ease with which the instrument can be made and used. The common mercury thermometer depends upon the expansion of mercury with rise in temperature. The mercury is contained in a bulb attached to a narrow graduated sealed tube; the expansion of the mercury in the bulb causes a thin thread of it to rise in the tube. See also *gas thermometer*; *pyrometers*; *resistance thermometer*; *thermocouple*; *Beckmann thermometer*; *thermometer, clinical*; *thermometer, maximum and minimum*.

thermometer, clinical A mercury *thermometer* designed to measure the *temperature* of the human body, and graduated to cover a range of a few degrees on either side of the normal body temperature. A constriction in the tube near the bulb causes the mercury thread to break when the thermometer is taken away from the warm body, and the mercury in the bulb starts to contract. The thread thus remains in the tube to indicate the maximum temperature reached, until it is shaken down.

thermometer, maximum and minimum A thermometer that records the highest and lowest *temperatures* reached during a period of time. It consists of a bulb filled with *alcohol*, which, by expansion, pushes a mercury thread along a fine tube, graduated in degrees. At each end

of the mercury thread is a small *steel* 'index' that is pushed by the mercury; one is thus left at the farthest point reached by the mercury thread, corresponding to the maximum temperature, and the other at the lowest point.

thermo-milliammeter An instrument for measuring small alternating *electric currents*. The current passes through a wire made of *constantan* or *platinum*, which is in contact with or very close to a *thermocouple*. The thermocouple is connected to a sensitive *milliammeter*, the heat of the constantan wire producing a thermoelectric current in the thermocouple; this current is recorded by the milliammeter. In a more sensitive instrument, the heater wire and thermocouple are arranged in an evacuated *quartz* envelope.

thermonuclear bomb See *nuclear weapons*.

thermonuclear reaction A *nuclear fusion* reaction in which the interacting particles or *nuceli* possess sufficient *kinetic energy*, as a result of their thermal agitation, to initiate and sustain the process. The hydrogen bomb (see *nuclear weapons*) makes use of thermonuclear reactions by employing a fission bomb to attain the required *temperature*, which is in excess of 20×10^6 °C. Controlled thermonuclear reactions attempt to make use of fusion reactions in *deuterium* and *tritium* gas at a temperature in the range 50×10^7 to 5×10^9 °C., for the purpose of generating *electrical energy*. The central problem in achieving this end is that of *containment*, i.e. separating the *plasma* (or high temperature ionized gas) from the walls of the containing vessel. In general, the plasma may be contained either by use of externally applied *magnetic fields*, or by the magnetic fields produced by currents flowing in the plasma itself (see *pinch effect*). The nature and instabilities of these magnetic fields are the subject of contemporary research. The machines in which these experiments are carried out may be classified according to whether the *magnetic lines of force* of the containing field are closed- or open-ended. The closed field group include *torus*-shaped machines, while the open-ended machines include those using *magnetic mirrors* or rotating plasmas.

thermopile An instrument for detecting and measuring *heat* radiations. It consists of a number of rods of antimony and bismuth, connected alternately in series. When the junctions are exposed to heat, the thermoelectric current produced (see *thermocouple*) may be detected or measured by a sensitive *galvanometer*.

thermoplastic A substance that becomes plastic on being heated; a *plastic* material that can be repeatedly melted or softened by heat without change of properties.

thermosetting plastics *Plastics* that, having once been subjected to *heat* (and *pressure*), lose their plasticity.

thermosphere The region of the *upper atmosphere* in which the

THERMOSTAT

- temperature* increases with *altitude*. See Fig. 44, under *upper atmosphere*.
- thermostat** An instrument for maintaining a constant *temperature* by the use of a device that cuts off the supply of *heat* when the required temperature is exceeded and automatically restores the supply when the temperature falls below that required. It usually consists of a *bimetallic strip* so arranged that when it is heated (or cooled) the power supply contacts are opened (or closed).
- thiamine** Aneurin. Vitamin B₁. C₁₂H₁₇ON₄SCl. A member of *vitamin B* complex; a white crystalline powder that is *soluble* in *water* and *alcohol*. It is widely required by many living *organisms* for the *metabolism* of *carbohydrates* and occurs in liver, milk, eggs, and fruit. Deficiency causes beriberi, and nervous disorders.
- thiazines** A group of *compounds* consisting of a six-membered ring, four of which are carbon atoms, one of which is a sulphur atom, and one a nitrogen atom.
- thiazole** $\text{S} \cdot \text{CH} : \text{N} : \text{CH} : \text{CH}$. A colourless *volatile liquid*, b.p. 116.8°C., whose *molecule* consists of a five-membered ring. *Derivatives* are used in dyestuffs and in medicine.
- thin-layer chromatography** A form of *chromatography* in which the stationary phase consists of a thin layer of alumina *slurry* on a glass plate. After selective absorption of the mobile phase the plate is dried in an oven. The technique is very similar to that of *paper chromatography*.
- thio-** Prefix denoting sulphur, in the naming of chemical *compounds*.
- thioacetamide** CH₃CSNH₂. A colourless *soluble* crystalline substance, m.p. 115–16°C., used as a source of *hydrogen sulphide*.
- thiocyanate** A salt or ester of *thiocyanic acid*.
- thiocyanic acid** HSCN. An *unstable acid* that forms salts called *thiocyanates*.
- thio ethers** A group of compounds with the general formula RSR', where R and R' are hydrocarbon radicals.
- Thiokols*** Rubber-like *polymer* materials of the general formula (RS_x)_n, where R is an *organic bivalent radical*, and x is usually between 2 and 4. They are very resistant to the swelling action of *oils*, and undergo a form of *vulcanization* on being heated with certain metallic *oxides*.
- thiolates** Metallic salts of *thiols*, formerly known as "mercaptides"; sulphur analogues of *alcoholates*.
- thiols** A class of organic compounds of the general formula RSH, with sulphur attached directly to carbon; they are the sulphur analogues of alcohols, containing SH instead of OH groups. Formerly called mercaptans.
- thionin** C₁₂H₉N₃S. A dark brown *thiazine derivative*, used as a dye in microscopy.

- thionyl chloride** SOCl_2 . A yellowish fuming liquid, b.p. 78°C ., used in organic synthesis.
- thiophene** $\text{C}_4\text{H}_4\text{S}$. A colourless liquid heterocyclic compound, b.p. 84.0°C ., with a nauseating stench. It occurs in coal-tar; used as a solvent and in the manufacture of dyes, plastics, and pharmaceutical products.
- thiosulphate** A salt or ester of thiosulphuric acid.
- thiosulphuric acid** $\text{H}_2\text{S}_2\text{O}_3$. An unstable acid formed by replacing one oxygen atom of sulphuric acid (H_2SO_4) by one sulphur atom. It is known only in solution or in the form of its salts or esters, the thiosulphates.
- thiourea** Thiocarbamide. $\text{NH}_2\text{CS.NH}_2$. A colourless organic compound, m.p. 180°C ., used in the manufacture of thiourea-aldehyde plastics.
- thixotropy** The rate of change of viscosity with time. Certain liquids, e.g. some paints, possess the property of increasing in viscosity with the passage of time when the liquid is left undisturbed. On shaking, the viscosity returns to its original value.
- Thomson effect** Kelvin effect. A temperature gradient along a conducting wire gives rise to an electric potential gradient along the wire. Named after Sir William Thomson (Lord Kelvin) (1824-1907).
- Thomson scattering** The scattering of photons of electromagnetic radiations by electrons according to J. J. Thomson's formula. Named after Sir Joseph John Thomson (1856-1940).
- thoria** See thorium dioxide.
- thorides** Natural radioisotopes that occur in the radioactive series containing thorium.
- thorite** A mineral consisting of thorium silicate, ThSiO_4 ; used as a source of thorium.
- thorium** Th. Element. A.W. 232.038. At. No. 90. A dark grey radioactive metal, r.d. 11.72, m.p. 1750°C . The most stable isotope, $^{232}_{90}\text{Th}$, has a half-life of 1.4×10^{10} years. Compounds occur in monazite and thorite. Used in alloys and as a source of nuclear energy.
- thorium dioxide** Thoria. ThO_2 . A white insoluble powder, m.p. 3050°C ., used in gas mantles, refractories and special glasses.
- thoron** A gaseous radioisotope of radon, $^{220}_{86}\text{Rn}$, produced by the disintegration of thorium. Half-life 51.5 seconds.
- threonine** A colourless soluble crystalline amino acid, m.p. 230°C ., that is essential to the diet of animals. See Appendix, Table 5.
- threshold** The lowest value of any stimulus, signal, or agency that will produce a specified effect. E.g. threshold frequency.
- threshold frequency** Light incident on a metal surface will give rise to the emission of electrons (see photoelectric effect) only if the frequency of the light is greater than a certain threshold value, which is characteristic of the metal used.

THROMBIN

thrombin An enzyme formed in the *blood* of vertebrates that acts upon *fibrinogen* to form *fibrin*; it is therefore essential to the process of blood clotting. Thrombin is formed from a blood *protein*, prothrombin.

thrombocytes See *blood platelets*.

thrust The propulsive force produced by a *reaction propulsion* motor. See also *specific impulse*.

thulium Tm. Element. A.W. 168.934. At. No. 69. R.d. 9.33, m.p. 1545°C. See *lanthanides*.

thymine 5-Methyluracil. $C_5H_6N_2O_2$. One of the two *pyrimidine* bases occurring in the *nucleotides* of *deoxyribonucleic acid*, which plays a part in the formulation of the *genetic code*.

thymol 3-Hydroxy-*p*-cymene. $C_{10}H_{14}O$. A white crystalline *phenol* derivative, m.p. 51.5°C., b.p. 233.5°C., that smells of thyme. It occurs in many *essential oils*; used as a mild *antiseptic*.

thyatron A gas-filled *thermionic valve* (usually a *triode*) in which a *voltage* applied to the *control grid* initiates, but does not limit, the *anode current*. Used as an *electronic switch*.

thyroxin(e) $C_{15}H_{11}I_4NO_4$. An iodine-containing *amino acid* produced by the thyroid gland. The pure form is a white crystalline substance, m.p. 236°C., used in cases of thyroid deficiency.

tides Movement of the seas caused by the attraction exerted upon the seas by the *Moon*, and to a lesser extent by the *Sun*. At full and new moon the tidal force of the Sun is added to that of the Moon, causing high spring tides; while at half-moons the forces are opposed, causing low neap tides. See Fig. 42.

timbre See *quality of sound*.

time dilation An effect predicted by the special theory of *relativity*. An observer measures the passage of a time t , on a clock travelling with him. Another observer travelling at a velocity v relative to the first has an identical clock travelling with him. It will appear to the first observer that a time $t(1 - v^2/c^2)$ will have elapsed on the second observer's clock (c is the *velocity of light*). The effect is only apparent at *relativistic velocities* and has been observed in the motions of some *mesons*, which have a longer life time at relativistic velocities.

time exposure A long *photographic* exposure in which the camera shutter is operated manually, or by some device not normally part of the camera.

time-lapse photography *Photography* in which a slow process, such as the growth of a plant, is photographed by a series of single exposures on cinematic film at regular intervals. When the film is projected at normal speed, the process is seen in a greatly speeded up version.

time measurement The *SI unit* of time is the *second* to which all time-measuring devices are ultimately referred. Such devices include the

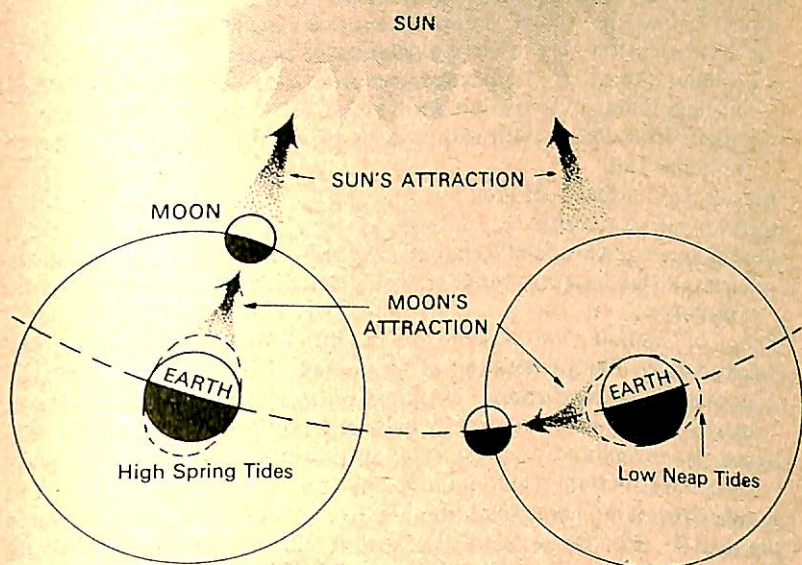


Figure 42.

pendulum, the quartz clock, the ammonia clock, and the caesium clock. See also year.

time reflection symmetry The proposition that any physical situation should be reversible in time. It is known to hold for *strong interactions* and *electromagnetic interactions*, but some doubt remains as to its validity with respect to *weak interactions*. According to this principle, if time could be reversed (i.e. run backwards) the time reflection of a particular physical situation would correspond to what one would normally see by reflecting the situation in a space mirror, except that all the particles would be replaced by their *anti-particles*. Thus, if left-polarized (see *parity*) *neutrinos* exist, right-polarized anti-particles must also exist: experimental evidence appears to confirm this.

tin Sn. (Stannum.) Element. A.W. 118.69. At. No. 50. A silvery-white metal, r.d. 7.31, m.p. 231.85°C., that is soft, malleable, and ductile. It is unaffected by air or water at ordinary temperatures. Tin occurs in two *allotropic* forms, white tin, the normal form of the metal, which below 13.2°C. passes into the powdery form known as grey tin. This causes *tin plaque* but can be prevented by the addition of small

TINCAL

amounts of antimony or bismuth. Tin is found in nature as *stannic oxide*, SnO_2 , *cassiterite* or tinstone. The metal is extracted by heating the *oxide* with powdered carbon in a *reverberatory furnace*. Used for tin-plating and in many *alloys*.

tincal An impure form of *sodium tetraborate* (*borax*).

tincture An alcoholic extract or a *solution in alcohol*.

tin plaque An allotropic change (see *allotropy*) in which white tin changes into a grey powdery form at 13.2°C .

tin plate Iron coated with a thin layer of tin, by dipping it into the molten *metal*.

tin salt See *stannous chloride*.

tinstone See *cassiterite*.

tintometer An instrument for comparing the colour of *solutions* with a series of standard solutions or stained glass slides. See also *Lovibond* tintometer*.

tints Colours that have the same *hue* but different *saturation*.

tissue culture The preparation of fragments of the *tissues* or *cells of organisms* for biochemical examination *in vitro*. Tissue cultures are usually maintained in correctly balanced *physiological saline*.

tissues A collection of similar *cells* and intercellular material, which form the structural material of a plant or animal.

titanic Containing *tetravalent* titanium.

titanium Ti. Element. A.W. 47.90, At. No. 22. A malleable and ductile *metal* resembling iron. R.d. 4.5, m.p. 1675°C . *Compounds* are fairly widely distributed, the principal ore being *rutile*. The metal is extracted by the *Kroll process*. Titanium is widely used where strong, light alloys are required, e.g. aircraft, missiles, etc.

titanium dioxide TiO_2 . A white insoluble powder, m.p. 1850°C . It occurs in nature in several crystalline forms, including *anatase* and *rutile*. Used as a white pigment in surface coatings and in the paper and textile industries, in ceramics, etc.

titanous Containing *trivalent* titanium.

titration An operation forming the basis of *volumetric analysis*. The addition of measured amounts of a *solution* of one reagent from a *burette* (called the 'titrant') to a definite amount of another reagent until the action between them is complete, i.e. till the second reagent is completely used up. (See *end point*.)

T.N.T. See *trinitrotoluene*.

tobacco mosaic virus TMV. A simple *virus* widely used in biochemical and biological studies, particularly concerning the transference of the *genetic code*. The virus particle consists of a single helix of *ribonucleic acid* containing some 6400 *nucleotides*, coated with about 2200 *molecules* of a single *protein*, each molecule of which comprises a *polypeptide* chain of 158 *amino acids* in a known sequence.

tocopherol Vitamin E. $C_{20}H_{30}H_2$. A yellow *insoluble* substance, m.p. 200–210°C. A *vitamin* that has been shown to prevent sterility in rats; deficiency in humans is associated with muscular dystrophy and vascular abnormalities. It occurs in vegetable leaves and wheat germ.

toluate A salt or ester of *toluic acid*.

toluene Toluol. $C_6H_5CH_3$. A *hydrocarbon* of the *benzene* series. A colourless inflammable *liquid* with a peculiar smell. B.p. 110°C. It occurs in *coal-tar*. Used in the preparation of *dyes*, *drugs*, *saccharin*, and *T.N.T.*

toluidine Aminotoluene. Methylaniline. $CH_3C_6H_4NH_2$. An aromatic amine that exists in three isomeric forms: *ortho*, *meta*, and *para*. The former two are liquids, b.p. 200–204°C., the third is a white crystalline solid, m.p. 45°C., b.p. 200°C.; all three are used as organic *intermediates*, especially in the manufacture of *dyes*.

toluol See *toluene*.

toluoyl The *univalent radical* $CH_3C_6H_4CO-$ (*ortho*-, *meta*-, and *para*-isomers), derived from the corresponding *toluic acids*, $CH_3C_6H_4COOH$.

tolyl The *univalent radical* $CH_3C_6H_4-$ (*ortho*-, *meta*-, and *para*-isomers).

tomography A technique for using *X-rays* for photographing one specific *plane* of the body, for diagnostic purposes.

tone of sound See *quality of sound*.

tonne Metric ton; 1000 kilograms; 2204.62 lbs, 0.9842 ton.

tonometer 1. An instrument for measuring the *pitch* of a *sound*, usually consisting of a set of calibrated *tuning forks*. 2. An instrument for measuring *vapour pressure*. 3. An instrument for measuring blood pressure, or the pressure within an eye-ball.

topaz A crystalline mineral, consisting of aluminium fluosilicate.

topology A branch of *geometry* concerned with the way in which figures are 'connected', rather than with their shape or size. Topology is thus concerned with the geometrical factors that remain unchanged when an object undergoes a continuous deformation (e.g. by bending, stretching, or twisting) without tearing or breaking.

toroidal Having the shape of a toroid or *torus*.

torque A *force*, *moment* of a force, or system of forces that tends to produce rotation.

torr A unit of *pressure* used in the field of high vacuum: equivalent to 1 mm of mercury. Equal to 133.322 newtons per square metre.

Torricellian vacuum The space, containing mercury vapour, that is produced at the top of a column of mercury when a long tube sealed at one end is filled with mercury and inverted in a trough of the metal. The mercury sinks in the tube until it is balanced by the atmospheric pressure (see *barometer*), the Torricellian vacuum

TORSION

being the space above it. Named after Evangelista Torricelli (1608-47).

torsion 'Twisting' about an *axis*, produced by the action of two opposing *couples* acting in parallel *planes*.

torsion balance If a wire is acted upon by a *couple* the *axis* of which coincides with the wire, the wire twists through an angle determined by the applied couple and the *rigidity modulus* of the wire. The amount of twist produced can thus be used to measure an applied *force*. In the torsion balance, the force to be measured is applied at right angles to, and at the end of, an arm attached to the wire.

torus (phys.) A 'doughnut' or anchor-ring shaped *solid* of circular or elliptical cross-section. If the cross-section is a circle of radius a , and the ring has a radius b , the volume of the torus is $2\pi^2 a^2 b$.

total internal reflection When *light* passes from one medium to another that is optically less dense, e.g. from *glass* to air (see *refraction* and *density, optical*), the *ray* is bent away from the *normal*. If the incident ray meets the surface at such an angle that the refracted ray must be bent away at an angle of more than 90° , the light cannot emerge at all, and is totally internally reflected.

totality The period in a total *eclipse* of the *Sun*, during which the bright surface of the Sun is totally obscured from view on *Earth* by the *Moon*.

tourmaline A class of natural crystalline *minerals*, consisting of *silicates* of various *metals* and containing boron. The *crystals* show some interesting *pyroelectric*, *piezoelectric* and optical *effects*. See *dichroism*.

toxic Poisonous.

toxicology The study of poisons.

toxin Poison; the name is generally confined to intensely poisonous substances produced by certain *bacteria*, which cause dangerous effects when they attack food or the human body.

trace element An *element* required in very small quantities by an *organism*. Such elements often form essential constituents of *enzymes*, *vitamins*, or *hormones*.

tracer See *radioactive tracing*.

trajectory The path of a *projectile*.

tranquillizer A *drug* used to reduce tension and anxiety, without impairing alertness or causing drowsiness.

transamination The transfer of an *amino group* from one *compound* (e.g. an *amino acid*) to another.

transcendental (math.) 1. (Of a number or quantity) Not capable of being expressed as the root of an algebraic *equation* with *rational coefficients*, e.g. π or e . 2. (Of a function) Not capable of being expressed by a finite number of algebraic operations, e.g. $\sin x$, e^x . (See *exponential*.)

transconductance The *mutual conductance* between the *control grid* of a *thermionic valve* and its *anode*; it is usually expressed in *siemens*.

transducer A device that receives waves (electrical, acoustical, or mechanical) from one or more media or transmission systems and supplies related waves (not necessarily of the same type as the input) to one or more other media or transmission systems. If the transducer derives *energy* from sources other than the input waves it is said to be 'active'; if the input waves are the only source of energy it is said to be 'passive'.

trans-form See *cis-trans isomerism*.

transformation, nuclear The change of one *nuclide* into another.

transformation constant See *disintegration constant*.

transformer A device by which an *alternating current* of one *voltage* is changed to another voltage, without alteration in *frequency*. A step-up transformer, which increases the voltage and diminishes the current, consists in principle of an iron core on which is wound a *primary coil* of a small number of turns of thick, insulated wire; and, forming a separate circuit, a secondary coil of a larger number of turns of thin, insulated wire. When the low-voltage current is passed through the primary coil, it induces a current in the secondary (see *induction*) by producing an alternating *magnetic field* in the iron core. The ratio of the voltage in the primary to that in the secondary is very nearly equal to the ratio of the number of turns in the primary to that in the secondary. The step-down transformer works on the same principle, with the coils reversed.

transient 1. (math.) A *function* whose value tends to zero as the independant *variable* tends to *infinity*. 2. (phys.) A short-lived oscillation in a system caused by a sudden change of *voltage*, *current*, or load.

transistor A *semiconductor* device capable of amplification in a similar manner to *thermionic valves*. It consists of two P-N *semiconductor junctions* back to back forming either a P-N-P or N-P-N structure. In a P-N-P transistor the thin central N-region is called the *base*, one P-region is called the *emitter*, the other the *collector*. In an N-P-N transistor the P-region is the base. In order to obtain amplification an N-P-N transistor is included in a circuit that supplies a positive *voltage* to the collector (N-region) and a negative voltage to the emitter (the other N-region). The collector in this type of transistor therefore corresponds to the *anode* of a thermionic valve while the emitter corresponds to the *cathode*. The base (P-region) is also positively biased and is analogous to the *control grid*. With this arrangement the large number of *electrons* in the emitter region is attracted to the P-layer, which, if it is sufficiently thin, will allow the electrons to pass through it and be attracted into the positive collector. The magnitude of the collector current will depend on the extent of the positive bias on the P-layer base. By suitable design the

device can be made to give a collector current some 20-100 times the base current. The advantages of a transistor over a valve are that it is less bulky and fragile, that it requires no heater current, and that the voltage at the collector need only be a few volts. A P-N-P transistor works in an exactly analogous manner to an N-P-N device, but the collector current consists mainly of *holes* instead of electrons. The device described here is a *junction transistor*, as this type has almost entirely replaced the earlier point-contact transistor. See also *field-effect transistor*.

transition, nuclear A change in the configuration of an atomic *nucleus*. It may involve a *transformation* (e.g. by *alpha-* or *beta-particle* emission) or a change in *energy level* by the emission of a *gamma-ray*.

transition elements *Elements* that have chemical properties resembling those of their horizontal neighbours in the *periodic table*. These elements have incomplete inner electron *shells* and are characterized by their variable *valences*: they occur in the middle of the long periods of the periodic table.

transition temperature 1. Transition point. The *temperature* at which one form of a polymorphous substance (see *polymorphism*) changes into another; the temperature at which both forms can co-exist. 2. See *superconductivity*.

translatory motion A motion that involves a non-reciprocating movement of *matter* from one place to another.

translucent Permitting the passage of *light* in such a way that an object cannot be seen clearly through the substance; e.g. frosted glass.

transmission coefficient Transmittance. *T*. When a *beam of light* (or other *electromagnetic radiation*) passes through a medium the radiation is absorbed to a greater or lesser extent (depending upon the medium and the *wavelength* of the radiation) and the intensity of the beam decreases. The ratio of the intensity after passing through unit distance of the medium to the original intensity is called the transmission coefficient.

transmission electron microscope See *electron microscope*.

transmittance See *transmission coefficient*.

transmitter 1. The equipment required to broadcast *electromagnetic radiation* of *radio frequencies*. The transmitter consists of devices for producing the *carrier wave*, *modulating* it, and feeding it to the *aerial* system. 2. The part of a *telephone* system that converts *sound* waves into *electric currents*, or the part of a *telegraph* system that converts mechanical movements into electrical currents.

transmutation of elements Changing one chemical *element* into another. Once the aim of *alchemy*; subsequently held to be impossible; with the present knowledge of *radioactivity* and atomic structure it is seen that the process goes on continuously in *radioactive* elements. Artificial transmutation by suitable *nuclear reactions* forms the

basis of experimental *nuclear physics*. See also *transition, nuclear*; *transformation, nuclear*.

transparent Permitting the passage of *light* in such a way that objects can be seen clearly through the substance.

transponder *Electronic* equipment designed to receive a specific signal and automatically transmit a reply.

transport number Transference number. The proportion of the total *electric current* passing through an *electrolyte* that is carried by a particular type of *ion*. The *anion* transport number plus the *cation* transport number equals unity.

transuranic elements *Elements* beyond uranium in the *periodic table*; i.e. elements of *atomic number* greater than 92. Such elements do not occur in Nature, but may be obtained by suitable *nuclear reactions*; they are all *radioactive* and members of the *actinide* group. See Appendix, Table 8.

transverse Cross-wise; in a direction at right angles to the length of the body under consideration.

transverse waves Waves in which the vibration or displacement takes place in a *plane* at right angles to the direction of propagation of the wave; e.g. *electromagnetic radiation*. See also *longitudinal waves*.

trapezium A *quadrilateral* having two of its sides parallel. The area of a trapezium having parallel sides *a* and *b* units in length, and vertical height *h* units is given by $h(a + b)/2$.

triad An *element* having a *valence* of three.

triangle A *plane* figure bounded by three straight lines. The three *angles* total 180° . The area of any triangle is given by the following expressions: 1. Half the *product* of one of the sides and the perpendicular upon it from the opposite vertex ($\frac{1}{2} \times \text{base} \times \text{height}$). 2. Half the product of any two of the sides and the *sine* of the angle between them ($\frac{1}{2} bc \sin A$). 3. $[s(s - a)(s - b)(s - c)]^{\frac{1}{2}}$, where *a*, *b*, and *c* are the lengths of the sides, and *s* is half the sum of *a*, *b*, and *c*.

triangle of forces If three *forces* acting at the same point can be represented in magnitude and direction by the sides of a *triangle* taken in order, they will be in *equilibrium*.

triangle of velocities If a body has three component *velocities* that can be represented in magnitude and direction by the sides of a *triangle* taken in order, the body will remain at rest.

triatomic Having three *atoms* in the *molecule*, e.g. *ozone*, O_3 ; having three replaceable atoms or *radicals* in the molecule.

triazine $C_3H_3N_3$. Three *isomeric compounds* having three nitrogen and three carbon *atoms* forming a six-membered ring. *Cyclonite* is a derivative of triazine.

triazole $C_2H_3N_3$. Four *isomeric compounds* having three nitrogen and two carbon *atoms* forming a five-membered ring.

TRIBASIC ACID

tribasic acid An acid having three atoms of acidic hydrogen in the molecule, thus giving rise to three possible series of salts; e.g. orthophosphoric acid, H_3PO_4 , can give rise to trisodium orthophosphate, Na_3PO_4 , disodium hydrogen orthophosphate, Na_2HPO_4 , and sodium dihydrogen orthophosphate, NaH_2PO_4 . (See sodium phosphate).

triboelectricity See *electricity, frictional*.

tribology The study of *friction* and lubrication.

triboluminescence The emission of *light* when certain crystals (e.g. cane-sugar) are crushed.

tribromoethanol $\text{CBr}_3\text{CH}_2\text{OH}$. A white crystalline powder, m.p. $79-82^\circ\text{C}$., used as a veterinary *anaesthetic*.

trichloroethylene $\text{CHCl}_2\text{CCl}_2$. A colourless *liquid*, b.p. 87°C .; widely used as industrial *solvent*, in dry cleaning, and as an *anaesthetic*.

triethanolamine See *ethanolamines*.

triethylamine $(\text{C}_2\text{H}_5)_3\text{N}$. A colourless *inflammable liquid*, b.p. $89-90^\circ\text{C}$., used as a *solvent*.

triglycerides See *glycerides*.

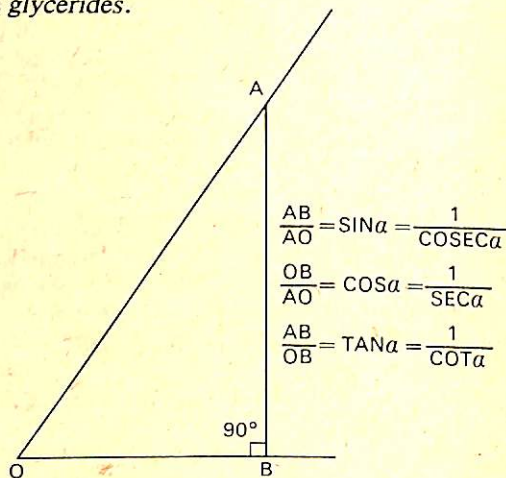


Figure 43.

trigonometrical ratios If a perpendicular AB is drawn from any point on arm OA of an angle AOB to the other arm, the following ratios are constant for the particular angle: AB/AO , sine ($\sin AOB$); OB/AO , cosine ($\cos AOB$); AB/OB , tangent ($\tan AOB$); AO/AB , cosecant ($\text{cosec } AOB$); AO/OB , secant ($\sec AOB$); and OB/AB , cotangent ($\cot AOB$). See Fig. 43.

trigonometry A branch of mathematics using the fact that numerous problems may be solved by the calculation of unknown parts (i.e. sides and angles) of a triangle when three parts are known. The

solution of such problems is greatly assisted by the use of the *trigonometrical ratios*.

trihydric Containing three *hydroxyl* groups in the *molecule*. See *triols*.

trihydroxybenzoic acid Gallic acid. $C_6H_2(OH)_3COOH$. A yellowish crystalline substance, used in *tanning* and the manufacture of *inks*.

trillion 10^{18} , a million million million (British); 10^{12} , a million million (American).

trimer A substance composed of *molecules* that are formed from three molecules of a *monomer*.

trinitrobenzene T.N.B. $C_6H_3(NO_2)_3$. Three *isomeric* crystalline compounds, m.p. $121-127^\circ C$., used as high *explosives*, and having greater power than T.N.T.

trinitrophenol See *picric acid*.

trinitrotoluene T.N.T. Trotyl. $C_7H_5(NO_2)_3$. A pale yellow, crystalline solid, m.p. $82^\circ C$., made by the *nitration* of *toluene*. A widely used high *explosive*.

triode* A *thermionic valve* containing three *electrodes*; an *anode* or plate, a *cathode*, and a *control grid*.

triolein Olein. $(C_{17}H_{33}COO)_3.C_3H_5$. A *glyceride* of *oleic acid*, b.p. $235-240^\circ C$. It is a *liquid* oil that occurs in many natural *fats and oils*.

triols Trihydric *alcohols* derived from *aliphatic hydrocarbons* by the substitution of *hydroxyl groups* for three of the *hydrogen atoms* in the *molecule*.

triose A *sugar* containing three *carbon atoms* in the *molecule*.

tripalmitin Palmitin. $(C_{15}H_{31}COO)_3.C_3H_5$. A *glyceride* of *palmitic acid*, m.p. $65.5^\circ C$., b.p. $310-320^\circ C$. It is a fat-like substance that occurs in palm-oil and many other natural *fats and oils*.

triple bond Three *covalent bonds* linking two *atoms* in a chemical compound, e.g. *acetylene*, $CH \equiv CH$.

triple point The point at which the *gaseous*, *liquid*, and *solid phases* of a substance are in *equilibrium*. For a given substance, the triple point occurs at a unique set of values of the *temperature*, *pressure*, and *volume*.

trisaccharides A group of *sugars* the *molecules* of which consist of three *monosaccharides*.

tristearin Stearin. $(C_{17}H_{35}COO)_3.C_3H_5$. A *glyceride* of *stearic acid*, m.p. $53.5^\circ C$. It is a fat-like substance that occurs in natural *fats*; it is formed by the *hydrogenation* of *triolein*. See *hydrogenation of oils*.

tritiated compound A *compound* in which some *hydrogen atoms* have been replaced by *tritium*, so that it may be used in *radioactive tracing*.

tritium T. 3H . A *radioactive isotope* of *hydrogen* with *mass number* 3 and *atomic mass* 3.016. The *abundance* of tritium in natural hydrogen is only one *atom* in 10^{17} , and its *half life* is 12.5 years. It

TRITON

can, however, be made artificially in *nuclear reactors* and *tritiated compounds* are used in *radioactive tracing*.

triton The *nucleus* of a *tritium atom*.

trivalent Tervalent. Having a *valence* of three.

trochoid A curve formed by a point on the radius of a *circle* as the circle rolls along a straight line. If the point is on the circumference of the circle the curve is a *cycloid*.

trochotron A multi-electrode *thermionic valve* used as a *scaler*.

trona A natural crystalline *double salt* of *sodium carbonate* and *sodium hydrogen carbonate*, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCC}_3 \cdot 2\text{H}_2\text{O}$, found in dried lakes.

troostite 1. The constituent of *steel* produced when *martensite* is *tempered* below 450°C ., consisting of *ferrite* and finely divided *cementite*. 2. Troostitic *pearlite*. The constituent of *steel* produced by the decomposition of *austenite* when cooled at a slower rate than yields *martensite* and a faster rate than yields *sorbite*.

tropical year See *year*.

tropine $\text{C}_8\text{H}_{15}\text{NO}$. A white crystalline *hygroscopic soluble alkaloid*, m.p. 63°C .

tropopause The boundary between the *troposphere* and the *stratosphere*.

troposphere The lower part of the Earth's *atmosphere* in which *temperature* decreases with height, except for local areas of 'temperature inversion'. See Fig. 44, under *upper atmosphere*.

trotyl See *trinitrotoluene*.

Trouton's rule The ratio of the *molar latent heat* of vaporization to the *boiling point in kelvin* is a constant for all substances. The rule is only approximate.

Troy weight 1 grain = 0.0648 gram.

20 grains = 1 scruple.

24 grains = 1 pennyweight.

3 scruples = 1 drachm.

8 drachms = 1 ounce Troy = 1.1 ounces avoirdupois.

trypsin An *enzyme* produced by the pancreas. In the process of digestion it breaks up *proteins* into *amino acids*.

tryptophan A colourless crystalline *amino acid*, m.p. $281-9^\circ\text{C}$., that is essential to the diet of animals and occurs in the seeds of some vegetables. See Appendix, Table 5.

tube of force A theoretical concept of a tube formed by the *lines of force* drawn out into space through every point on a small closed curve upon the surface of a charged *conductor*.

tungstate A *salt* of *tungstic acid*.

tungsten W. Wolfram. Element. A.W. 183.85. At. No. 74. A grey hard ductile malleable metal that is resistant to *corrosion*, r.d. 19.3, m.p. 3410°C . It occurs as *wolframite*, FeWO_4 , and *scheelite*, CaWO_4 , and is obtained by converting the ore to the oxide and then

reducing the latter. Used in *alloys*, in cemented *carbides* for hard tools, and for electric lamp *filaments*. The names *tungsten* and *wolfram* for this element were both officially recognized in 1951.

tungsten carbide WC. A grey powder, m.p. 2780°C., obtained by direct combination of tungsten and carbon at 1600°C. It is almost as hard as *diamond* and is used in making abrasives and tools.

tungsten trioxide WO₃. A yellow *insoluble* powder, m.p. 1473°C., used in the manufacture of *tungstates*.

tungstic acid H₂WO₄. *Hydrated tungsten trioxide*. A white crystalline powder that loses a *molecule* of water at 100°C., used in the manufacture of lamp *filaments*.

tuning, radio See *resonant circuit*.

tuning fork A two-pronged *metal* fork that, when struck, produces a pure *tone* of constant specified *pitch*. Used in *acoustics* and for tuning musical instruments.

tunnel diode A *semiconductor* device that has negative *resistance* over a part of its operating range. It consists of a P-N *semiconductor junction* in which both the P- and N- regions contain very large numbers of impurity *atoms*, thus producing a high *potential* barrier at the junction. If a small *voltage* is applied to the device, positive at the P- region, an *electron* current will flow (despite the high potential barrier) as a result of the *tunnel effect*. After a certain voltage has been reached this effect is reduced and the current declines with increasing voltage, thus exhibiting the negative resistance characteristic. At higher voltages the normal *majority carrier* current flows and the current again increases with voltage. Used in switching circuits and where low noise amplification is required up to *frequencies* of about 1000 *megahertz*.

tunnel effect The passage of an *electron* through a narrow *potential* barrier in a *semiconductor*, despite the fact that, according to classical *mechanics*, the electron does not possess sufficient *energy* to surmount the barrier. It is explained by *quantum mechanics* on the assumption that electrons are not completely localized in *space*, a part of the energy of the wave associated with the electron being able to 'tunnel' through the barrier.

turbine Any motor in which a shaft is steadily rotated by the impact or reaction of a current of *steam*, air, *water*, or other *fluid* upon blades of a wheel. In an 'impulse' turbine the fluid is directed from jets or nozzles on to the *rotor* blades. In a 'reaction' turbine a ring of stationary blades replaces the nozzles and the rotor is driven by reaction between the fluid, the stationary blades, and the rotor blades. Many turbines work on a combination of the reaction and impulse principles. See also *gas turbine*.

turbogenerator A steam *turbine* coupled to an electric *generator* for the production of *electric power*. It is the usual arrangement in a 'conventional' power station.

TURBULENT FLOW

turbulent flow The type of *fluid* flow in which the motion at any point varies rapidly in direction and magnitude.

Turkey-red oil A mixture of sulphate esters obtained by treatment of *castor oil* with *sulphuric acid*. Used in dyeing.

turpentine Oil of turpentine. A *liquid* extracted by *distillation* of the *resin* of pine trees. B.p. 155°-165°C. It is composed chiefly of *pinene*. Used as a *solvent*.

turquoise Natural basic aluminium phosphate, coloured blue or green by traces of copper.

Twaddell scale A scale for measuring the *relative density* of *liquids*. Degrees Twaddell = 200 (r.d. - 1); r.d. = 1 + degrees Twaddell/200. Named after W. Twaddell (19th century).

tweeter A *loudspeaker* designed to reproduce the higher *audiofrequency* sounds, i.e. 5-15 kilohertz.

Tyndall effect The *scattering of light* by particles of *matter* in the path of the light, thus making a visible 'beam', such as is caused by a ray of light illuminating particles of dust floating in the air of a room. Named after John Tyndall (1820-93).

type metal An *alloy* of 60% lead, 30% antimony, and 10% tin. Owing to the presence of antimony it expands on solidifying and thus gives a sharp cast.

tyrosine A white crystalline *amino acid*, m.p. 310°-320°C., obtained from most *proteins*. See Appendix, Table 5.

U

udometer Pluviometer. A rain gauge.

ultimate stress Tenacity. The load required to fracture a material divided by its original area of cross-section at the point of fracture. The ultimate stress is divided by the 'factor of safety', in order to obtain the 'working stress'.

ultracentrifuge A high speed *centrifuge*. It is used in the determination of the *molecular weights* of large *molecules* in high *polymers* and *proteins*.

ultra-high frequencies U.H.F. *Radio frequencies* in the range 300 to 3000 *megahertz*.

ultramarine An artificial form of *lapis lazuli*, made by heating together *clay*, *sodium sulphate*, carbon, and sulphur.

ultramicrobalance A *balance* for weighing accurately to 10^{-8} gram.

ultramicroscope An instrument, making use of the *Tyndall effect* for showing the presence of particles that are too small to be seen with the ordinary *microscope*. A powerful *beam of light* is brought to a focus in the *liquid* that is being examined; suspended particles appear as bright specks by *scattering the light*.

ultrasonic frequency A *frequency* in excess of about 20 000 *hertz*.

ultrasonic generator A device for the production of pressure waves of *ultrasonic frequency*.

ultrasonics Supersonics. The study of pressure waves that are of the same nature as *sound waves*, but that have frequencies above the audible limit.

ultraviolet microscope A *microscope* in which the object is illuminated by *ultraviolet radiation*. *Quartz lenses* are used and the image is recorded photographically. As ultraviolet radiation is of shorter *wavelength* than visible *light*, greater magnification can be obtained than with an optical microscope.

ultraviolet radiation *Electromagnetic radiation* in the *wavelength* range of approximately 4×10^{-7} to 5×10^{-9} *metre*; i.e. between visible *light waves* and X-rays. The longest ultraviolet waves have wavelengths just shorter than those of violet light, the shortest perceptible by the human eye. They affect photographic *films* and plates; their action on *ergosterol* in the human body produces *vitamin D*. Radiation from the *Sun* is rich in such rays but most of it is absorbed by the *ozone layer* in the *upper atmosphere*. Ultraviolet radiation is produced artificially by the *mercury vapour lamp*.

umbra A region of complete shadow. See Fig. 38 under *shadow*.

UNCERTAINTY PRINCIPLE

uncertainty principle Indeterminacy principle. It is impossible to determine with accuracy both the position and the *momentum* of a particle (e.g. an *electron*) simultaneously. The more accurately the position is known, the less accurately can the momentum be determined. If the range of values for the position is Δp , and the range of values for the momentum Δm , then $\Delta p \cdot \Delta m = h$, where h is *Planck's constant*. The principle, which was first stated by Werner Heisenberg, (1901-76) arises from the dual particle wave nature of matter. See *De Broglie wavelength*.

unfilled aperture A method of constructing a *radio telescope* in which two *aerials* of different shapes are combined into one *radio interferometer* in such a way that only two perpendicular arms of the aerial system are built, giving the effect of two large apertures. The two arms may be spaced at varying distances apart, or they may be superimposed upon one another as in the 'Mills Cross' radio telescope. Unfilled aperture telescopes are suitable for use at long *wavelengths*.

ungula A part of a *cylinder* or *cone* that is cut off by a *plane* not parallel to its base.

uniaxial crystal A double refracting *crystal* possessing only one *optic axis*.

unicellular (Of an *organism*.) Consisting of only one *cell* (e.g. *bacteria*, *protozoa*, etc.).

unified field theory A theory that attempts to describe the electromagnetic and *gravitational fields* in one set of *equations*. No such satisfactory theory has yet been devised. To achieve complete unification the theory would also have to explain *strong* and *weak interactions*.

unit A quantity or dimension adopted as a standard of measurement.

unitary symmetry SU3. A method of classifying *elementary particles* according to their properties in a similar manner to the classification of atomic properties in the *periodic table*. SU3 has successfully predicted the existence of particles that have subsequently been detected experimentally, e.g. omega-minus (see Appendix, Table 6). The concept of SU3 has been extended to a larger symmetry group, called SU4, which leads to the concept known as *charm*.

unit cell The unit of which a crystal *lattice* is constructed. For example, the *body-centred* and *face-centred* lattices are forms of a cubic unit cell.

unity (math.) One.

univalent (chem.) Monovalent. Having a *valence* of one.

Universe The total of all the *matter*, *energy*, and *space* that man is capable of experiencing, or whose existence he can deduce or has grounds for postulating. The universe is currently best described in terms of a four-dimensional curved *space-time continuum* (see

relativity); it contains some 10^{41} kilograms of matter, collected in some 10^9 galaxies. See *heat death of the Universe*, *steady state theory*, *superdense theory*.

unsaturated compound (chem.) A compound having some of the atoms in its molecule linked by more than one valence bond (see *double bond* and *triple bond*); a compound that can form additional compounds.

unstable (chem.) Easily decomposed.

unstable equilibrium See *stable equilibrium*.

upper atmosphere The upper atmosphere of the Earth is usually taken to include its gaseous envelope from 30 kilometres upwards (i.e. the part of the atmosphere that is inaccessible to direct observations by balloons). Information is obtained from space probes and artificial Earth satellites. See Fig 44.

Up to about 100 km the composition of the upper atmosphere is similar to that at ground level (see *atmosphere*). Above this height the dissociation of oxygen into atoms is almost complete, and at above 150 km the nitrogen separates out owing to its greater mass so that monatomic oxygen predominates. There is considerable ionization in the upper atmosphere as a result of solar ultraviolet radiation and X-rays. See *ionosphere*.

uracil Pyrimidinedione. $C_4H_4N_2O_2$. A white crystalline pyrimidine base, m.p. $338^\circ C$., that occurs in the nucleotides of ribonucleic acid.

uranic Containing tetravalent uranium.

uranium U. Naturally occurring radioactive element. A.W. 238.03, At. No. 92. A hard white metal, r.d. 18.95, m.p. $1132^\circ C$. The natural element consists of 99.28% $^{238}_{92}U$ (half-life 4.5×10^9 years) and 0.71% $^{235}_{92}U$ (half-life 7.1×10^8 years). The latter isotope is capable of sustaining a nuclear chain reaction and is of greater importance in nuclear reactors and nuclear weapons. The principal ore is pitchblende.

uranium dioxide UO_2 . A black insoluble crystalline radioactive substance, m.p. $2500^\circ C$., used as a fuel in advanced gas-cooled reactors.

uranium trioxide Uranic acid, uranyl oxide. UO_3 . A red insoluble radioactive powder, which decomposes on heating.

uranous Containing trivalent uranium.

Uranus (astr.) A planet possessing five satellites, with its orbit lying between those of Saturn and Neptune. Mean distance from the Sun, 2869.6 million kilometres. Sidereal period ('year') 84 years. Mass approximately 14.52 times that of the Earth, diameter 47 100 kilometres. Surface temperature, about $-180^\circ C$.

uranyl The bivalent group, $=UO_2$, which forms salts with acids.

urea Carbamide. $CO(NH_2)_2$. A white crystalline organic compound, m.p. $132^\circ C$., that occurs in urine. It was the first organic compound

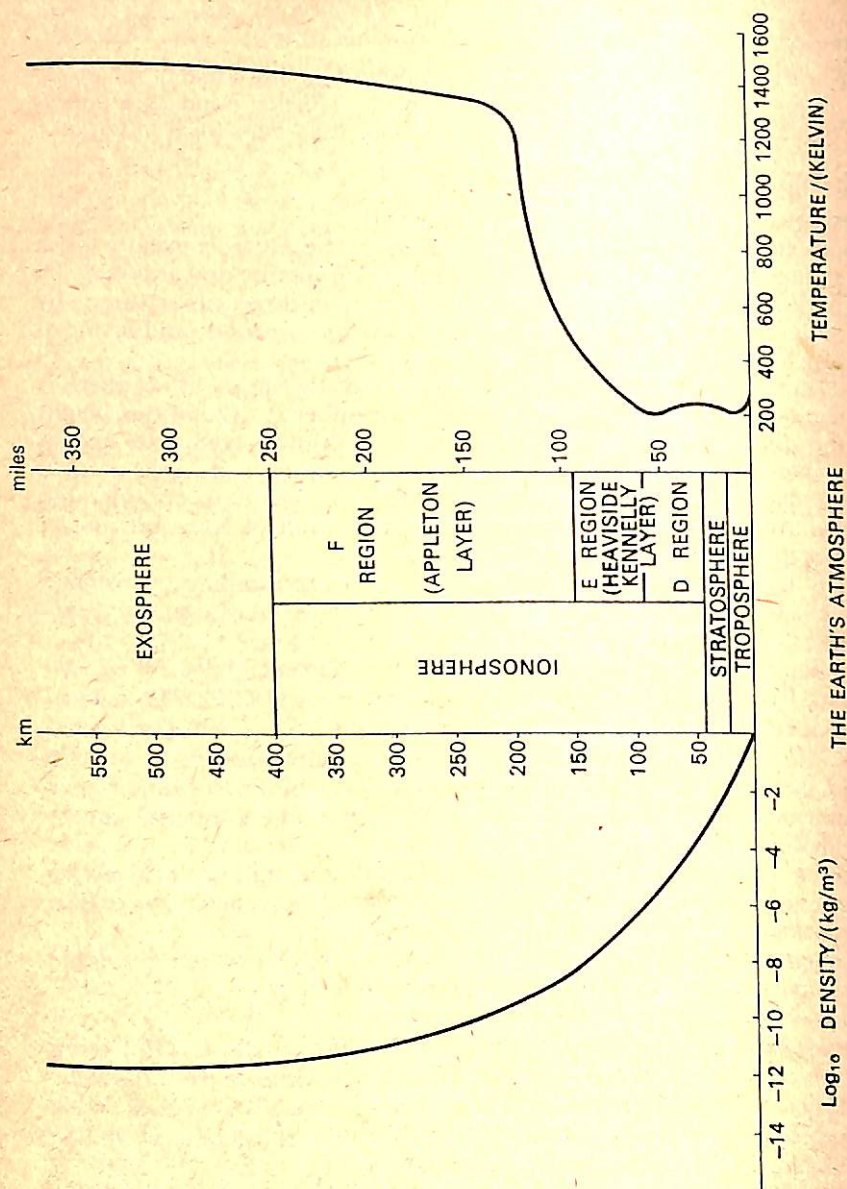


Figure 44.

to be prepared artificially. Used as a *fertilizer*, in medicine, and in *urea-formaldehyde resins*.

urea-formaldehyde resins *Thermosetting resins* with good oil resistant properties, produced by the condensation *polymerization* of *urea* and *formaldehyde*.

urease An *enzyme* capable of splitting *urea* into *ammonia* and *water*.

ureido The *univalent radical*, $\text{NH}_2\text{CONH}-$, derived from *urea*.

urethane resins Polyurethanes. A class of *polymers* chemically related to *urethanes*, generally made by condensation of *isocyanates* with *polyhydric* compounds. They form valuable materials for a number of purposes, including the manufacture of coatings and foam plastics.

urethan(e)s *Esters* of carbamic acid, NH_2COOH . The name is usually applied to ethyl carbamate, $\text{NH}_2\text{COOC}_2\text{H}_5$.

ureylene group The *divalent radical*, $-\text{NHCONH}-$, derived from *urea*.

uric acid $\text{C}_5\text{H}_4\text{N}_3\text{O}_4$. An *organic acid*, belonging to the *purine* group; a colourless crystalline *solid* that is slightly *soluble* in *water*. It occurs in very small amounts in the urine of some animals as a breakdown product of *amino acids* and *nucleic acids*. Sodium and potassium *salts* of the acid are deposited in the joints in cases of *gout*.

urotropine See *hexamethylene tetramine*.

vacancy Schottky defect. An irregularity that occurs in a *crystal lattice* when a site normally occupied by an *atom* or *ion* is unoccupied. See *defect*.

vaccine A preparation containing *viruses* or other *microorganisms* (either killed or of attenuated virulence) that is introduced into the human system to stimulate the formation of *antibodies*. In this way immunity (partial or complete) to subsequent infection by this type of microorganism is conferred.

vacuum A *space* in which there are no *molecules* or *atoms*. A perfect vacuum is unobtainable, since every material that surrounds a space has a definite *vapour pressure*. The term is generally taken to mean a space containing air or other gas at very low *pressure*. A low (or soft) vacuum is one in which the pressure is above 10^{-4} mmHg, while in a high (or hard) vacuum it is below this figure. 'Ultra-high' vacua (i.e. vacua in which the pressure does not exceed 10^{-9} mmHg or 10^{-7} Pa) occur naturally at heights of more than 800 kilometres above the *Earth's* surface, and by special techniques pressures of 10^{-13} torr can be achieved in the laboratory.

vacuum distillation The process of *distillation* carried out at a reduced *pressure*. The reduction in pressure is accompanied by a depression in the *boiling point* of the substance to be distilled, thus lower *temperatures* can be employed. This process therefore enables substances to be distilled, which at normal pressures would decompose.

vacuum evaporation A technique for covering a solid surface with a thin layer of a substance. The substance is heated in a *vacuum*, the atoms escaping from its surface being allowed to condense on the surface to be coated.

vacuum pump Any device used to produce a low pressure. The common type of rotary oil pump can produce pressures down to 10^{-3} mmHg, below this pressure a *condensation* pump is required.

vacuum tube See *thermionic valve*; *discharge in gases*.

valence The combining power of an *atom*; the number of hydrogen atoms that an atom will combine with or replace. E.g. the valence of oxygen in water, H_2O , is 2.

valence, electronic theory of An explanation of *valence* on the basis of atomic structure (see *atom, structure of*), and particularly on the assumption that certain arrangements of outer *electrons* in *atoms* (e.g. *octets* or outer *shells* of eight electrons) are stable and tend to be formed by the transfer or sharing of electrons between atoms. The chief types of linkage are: (1) electrovalent bonds formed by

the transfer of electrons from one atom to another; the atom that loses an electron becomes a positive *ion*, and the other a negative ion. This provides an explanation of the behaviour of *electrolytes*.

(2) Covalent bonds. The sharing of a pair of electrons, one being provided by each atom. This applies to many non-ionizable bonds, e.g. those in *organic compounds*. If both electrons in a covalent bond are donated by the same atom, the bond is referred to as a coordinate or dative bond. Many bonds possess electronic configurations intermediate between the above forms. See *resonance* (chem.); *benzene ring*; *hydrogen bond*.

valence band The range of energies (see *energy bands*) in a *semiconductor* corresponding to states that can be occupied by the *valence electrons* binding the *crystal* together. Electrons missing from the valence band give rise to *holes*.

valence bond The link holding *atoms* together in a *molecule*. In the case of two *univalent* atoms joined together, a single valence bond holds them together; it is possible for an atom to satisfy two or three valence bonds of another atom, giving rise to a *double* or *triple bond*.

valence electron An outer *electron* of an *atom* that takes part in formation of a *valence bond*.

valeric acid Pentanoic acid. C_4H_9COOH . A *fatty acid* that exists in several *isomeric* forms, the common form being a colourless *liquid* with a pungent odour, b.p. $186-7^\circ C$., used in perfumes.

valine A white crystalline *soluble amino acid* that occurs in most *proteins*. Used in medicine and *culture media*. See Appendix, Table 5.

valve, wireless See *thermionic valve*.

vanadate A *salt* or *ester* of *vanadic acid*.

vanadic acid HVO_3 . A yellow *insoluble* crystalline substance. Other *acids* are formed by the addition of *water molecules*, e.g. H_3VO_4 .

vanadium V. Element. A.W. 50.942. At. No. 23. A very hard white *metal*, r.d. 6.11, m.p. $1890^\circ C$. It occurs in a few rather rare *minerals*, such as *carnotite* and *patronite*. It is used in *vanadium steels*.

vanadyl The *divalent* group = VO_2 , which forms *salts* with *acids*.

Van Allen radiation belts Two belts of charged particles trapped within the Earth's *magnetic field*, which were discovered by J. Van Allen (born 1914) in 1958 from the results of artificial *satellite* and *space probe* experiments. The inner belt, ranging from 2400 to 5600 km above the Earth's surface, is believed to consist of secondary charged particles emitted by the Earth's *atmosphere* as a consequence of the impact of *cosmic rays*. The outer belt lies between 13 000 and 19 000 km above the Earth, and it is believed that the particles it contains originate from the *Sun*.

Van de Graaff generator An *electrostatic generator* used for accelera-

VAN DER WAALS' EQUATION

ting charged particles of atomic magnitudes, e.g. *protons*, to high *energies*. Named after R. J. Van de Graaff (1901-1967).

Van der Waals' equation of state $(p + a/v^2)(v - b) = RT$ for a mole of a substance in the gaseous and liquid phases where p = pressure, v = volume, T = absolute temperature, R = the gas constant; a/v^2 is a correction for the mutual attraction of the molecules (see *Van der Waals' forces*), and b is a correction for the actual volume of the molecules themselves. The equation represents the behaviour of ordinary gases more correctly than the perfect gas equation $p v = RT$. Named after J. D. Van der Waals (1837-1923).

Van der Waals' force An attractive force existing between atoms or molecules of all substances. The force arises as a result of electrons in neighbouring atoms or molecules (see *atom, structure of*) moving in sympathy with one another. This force is responsible for the term a/v^2 in *Van der Waals' equation of state*. In many substances this force is small compared with the other inter-atomic attractive and repulsive forces present.

vanillin $\text{CH}_3\text{O}(\text{OH})\text{C}_6\text{H}_3\text{CHO}$. A white insoluble crystalline substance, m.p. 80-81°C., obtained from vanilla beans synthesized from *lignin*; used as a flavour and in perfumes.

Van't Hoff's law The osmotic pressure of a dilute solution is equal to the pressure that the solute would exert in the gaseous state, if it occupied a volume equal to the volume of the solution, at the same temperature. Named after Jacobus Van't Hoff (1852-1911).

vapour A substance in the gaseous state that can be liquefied by increasing the pressure without altering the temperature. A gas below its critical temperature.

vapour density A measure of the density of a gas or vapour; usually given relative to oxygen or hydrogen. The latter is the ratio of the mass of a certain volume of the gas to the mass of an equal volume of hydrogen, measured under the same conditions of temperature and pressure. Numerically this ratio is equal to half the molecular weight of the gas.

vapour pressure All liquids and solids give off vapour, consisting of molecules of the substance. If the substance is in an enclosed space, the pressure of the vapour will reach a maximum that depends only upon the nature of the substance and the temperature; the vapour is then saturated and its pressure is the saturated vapour pressure.

varec Kelp. The ash of seaweed, from which iodine is extracted.

variable (math.) 1. A symbol or term that assumes, or to which may be assigned, different numerical values. An 'independent variable' is a variable in a function that determines the value of other variables. A 'dependent variable' has its value determined by other variables. E.g. in $y = 5x^2 + 2$, x is the independent variable and y is the dependent variable. 2. Not constant.

- variance** 1. (statistics) The *square* of the mean *deviation*. 2. (chem.) The number of *degrees of freedom* that a system can have.
- variate** (statistics) A *variable* that can have any of a set of values according to specified *probabilities*.
- variation** (math.) If a quantity y is some *function* of another quantity x , i.e. if $y = f(x)$, then, as x varies, y varies in a manner determined by the function. If $f(x) = x \times a$ (where a is a constant), then y is said to vary directly as x , or to be directly proportional to x , $y = ax$. If $f(x) = a/x$, y is said to vary inversely as x , or to be inversely proportional to x ; $y = a/x$.
- variometer** A *variable inductance* consisting of two coils in *series*, arranged so that one coil can rotate within the other. It is also used as a means of measuring inductance.
- Vaseline*** See *petrolatum*.
- vat dyes** A class of *insoluble dyes* that are applied by first reducing them to leuco-compounds, which are *soluble* in *alkalis*. The *solution* is applied to the material, and the insoluble dye is regenerated in the fibres by *oxidation*. *Indigo* and many synthetic dyes belong to this class.
- vector** Any physical quantity that requires a direction to be stated in order to define it completely. E.g. *velocity*.
- vectors, parallelogram law of** If a particle is under the action of two like *vector* quantities, which are represented by the two sides of a *parallelogram* drawn from a point, the *resultant* of the two vectors is represented in magnitude and direction by the diagonal of the parallelogram drawn through the point.
- vectors, triangle law of** If a particle is acted upon by two *vector* quantities represented by two sides of a *triangle* taken in order, the *resultant* vector is represented by the third side of the triangle.
- vegetable oils** Oils obtained from the leaves, fruit, or seeds of plants; they consist of *esters of fatty acids* and *glycerol*. See also *fats* and *oils*.
- velocities, parallelogram of** A special case of the parallelogram of *vectors*. See *parallelogram of velocities*.
- velocities, triangle of** A special case of the triangle of *vectors*. See *triangle of velocities*.
- velocity** The rate of motion in a given direction; measured as length per unit time.
- velocity, relative** The *velocity* of one body relative to another is the rate at which the first body is changing its position with respect to the second. If the velocities of two bodies are represented by two sides of a *triangle* taken in order, their relative velocity is represented by the third side.
- velocity modulation** The *modulation* of the *velocity* of a stream of *electrons* by alternately accelerating and decelerating them. See also *klystron*.

VELOCITY OF LIGHT

velocity of light See *light*, *velocity of*.

velocity ratio of a machine The ratio of the distance through which the point of application of the applied *force* moves, to the distance through which the point of application of the resistance moves in the same time. For an 'ideal' machine, which requires no *energy* to move its component parts, the velocity ratio is equal to the *mechanical advantage*.

Venetian white A mixture of *white lead* and *barium sulphate*, BaSO_4 , in equal parts. Used in *paints*.

Venturi tube A device for measuring the rate of flow of a *fluid*; it consists of an open-ended tube flared at each end, so that the fluid *velocity* in the narrow central portion is higher than at the flared ends. The fluid velocity can be calculated from the difference in *pressure* between the centre and the ends. Named after G. B. Venturi (1746-1822).

Venus (astr.) A *planet* with its *orbit* between those of *Mercury* and the *Earth*. Mean distance from the *Sun*, 108.21 million kilometres. *Sidereal period* ('year'), 224.701 days. *Mass*, approximately 0.815 that of the *Earth*, diameter 12 300 kilometres. There is no evidence of oxygen in the *atmosphere* of the planet, but the *Mariner space probe* indicated that its surface temperature is about 425°C . and that it is covered by a dense cloud layer with freezing temperatures high up in the atmosphere.

verdigris A green deposit formed upon copper; it consists of *basic copper carbonate* or *sulphate* of variable composition.

vermicide A substance used to kill worms.

vermiculite A group of low-grade *micas* that expand and exfoliate on heating to a light water-absorbent material. Used in the exfoliated form as *heat* and *sound* insulating materials, and in special (potting) *soils*.

vermifuge A substance used for expelling (or killing) intestinal worms.

vermilion A scarlet form of *mercuric sulphide*, HgS ; used as a *pigment*.

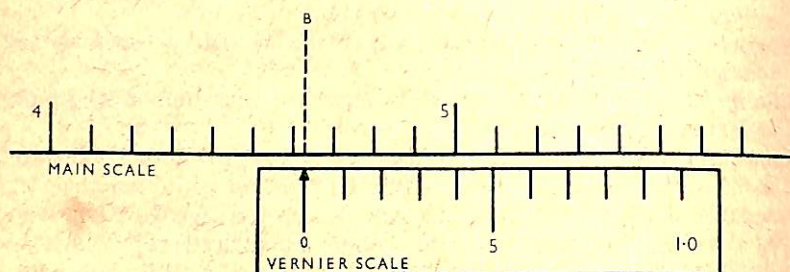


Figure 45.

vernier A device for measuring subdivisions of a scale. For a scale graduated in (say) centimetres and tenths, a vernier consists of a scale that slides alongside the main scale, and on which a length of nine-tenths of a cm is subdivided into ten equal parts. Each vernier division is thus 0.09 cm. If it is desired to measure a length *AB*, the main scale is placed with its zero mark at *A*, and the vernier scale is slid till its zero mark is at *B*. By noting which division on the vernier scale is exactly in line with a division on the main scale, the second decimal place of the length *AB* is obtained. Thus, if *B* falls between 4.6 and 4.7 cm on the main scale, and the fourth division on the vernier scale is just in line with a main scale division line, the length *AB* is 4.64 cm. See Fig. 45. Named after Pierre Vernier (1580-1637).

vernier motor (engine) A small *rocket* motor used to correct the flight path or *velocity* of a missile or *spacecraft*.

Veronal* Diethylbarbituric acid, barbital. $C_8H_{12}N_2O_3$. A white crystalline *barbiturate*, m.p. 191°C., used as a *hypnotic*.

versed sine One minus the cosine of an angle (see *trigonometrical ratios*).

vertex 1. (math.) The point on a geometrical figure furthest from the *base*. 2. (astr.) The point on the *celestial sphere* towards which, or from which, a *star* appears to move.

very high frequencies VHF. *Radio frequencies* in the range 30 to 300 *megahertz*.

very low frequencies VLF. *Radio frequencies* below 30 *kilohertz*.

vesicant Blister-producing.

vibration, plane of See *polarization of light*.

vicinal When two similar *substituents* are added to a carbon compound, the positions of the substituents (or the molecule itself) are referred to as 'vicinal' (or *vic-*) if the substituents have attached to adjacent carbons and 'gem' if they have attached to the same carbon atom.

video frequency signal The signal that transmits the picture and synchronizing information in a *television* system.

vinasse The residual *liquid* obtained after *fermentation* and *distillation* of beetroot molasses. Used as a source of *potassium carbonate*.

vinegar A *liquid* containing 3%-6% *acetic acid*, obtained by the *oxidation* of *ethanol* by the action of *bacteria* on wine, beer, or fermented wort.

vinyl The *unsaturated univalent radical* $CH_2:CH-$.

vinyl acetate $CH_2:CHOOCCCH_3$. A colourless *insoluble liquid*, b.p. 71-2°C., that *polymerizes* to form *polyvinyl acetate*.

vinyl chloride Chloroethene. $CH_2:CHCl$. A colourless *gas*, b.p. -13.9°C., that *polymerizes* to form *polyvinyl chloride*. Used as a *refrigerant* in the unpolymerized form.

vinylene The *bivalent radical* $-CH:CH-$.

VINYL ETHER

vinyl ether See *divinyl ether*.

vinylidene The *unsaturated bivalent radical* $\text{CH}_2\text{:CH=}$.

vinylidene chloride $\text{CH}_2\text{:CCl}_2$. A colourless inflammable *liquid*, b.p. 32°C ., that *polymerizes* to form *polyvinylidene chloride*.

virgin neutrons *Neutrons*, produced by any means, before they have experienced a collision.

virial equation A *gas law* that attempts to account for the behaviour of a real gas. It usually takes the form:

$$pv = RT + Bp + Cp^2 + Dp^3 \dots,$$

where B,C,D are empirical constants known as the virial coefficients.

virology The study of *viruses* and the diseases they cause.

virtual image See *image, virtual*.

virtual state In *classical physics* a *force* between bodies not in contact (e.g. electrostatic repulsion) is represented by a *field*. In *quantum mechanics* this force may be represented by an exchange of particles between the interacting bodies. The exchanged particle is not in a 'real' state, however, although its properties can be calculated; such a particle is described as existing in the virtual state. E.g. electrically charged particles may be visualized as interacting as the result of the exchange of virtual *photons*. A virtual particle that is responsible for a force can, by the addition of *energy* to the system, be converted into a real particle. The virtual state depends upon the concept of indeterminism expressed in the *uncertainty principle*.

virtual work If a body, acted upon by a system of *forces*, is imagined to undergo a small displacement, then in general the forces will do *work*, termed the virtual work of the forces. If the body is in *equilibrium*, the total virtual work done is zero. This principle of virtual work is used to determine the positions of equilibrium of a body or a system of bodies under the action of given forces, and to determine relations between the forces acting on such a system in a given equilibrium position.

virus A disease-producing particle, too small to be seen by an optical *microscope* but visible with an *electron microscope*. Viruses are only capable of multiplication within a living *cell*, each type of virus requiring a specific host cell. The simplest viruses consist of a single helical strand of *ribonucleic acid* coated with *protein molecules* (see *tobacco mosaic virus*). The active principle of these viruses resides in the RNA as it is only this part of the particle that enters the cell. Other viruses are considerably more complex and may be up to 0.2 *micrometre* in diameter. Viruses are considered to be on the borderline between the animate and the inanimate. See also *bacteriophage*.

viscometer An instrument for the measurement of *viscosity*.

viscose A thick treacly brownish *liquid*, consisting mainly of a *solution* of cellulose *xanthate* in dilute *sodium hydroxide*. It is made from *cellulose* by the action of sodium hydroxide and *carbon disulphide*. Used for the production of viscose *rayon* and of cellulose film, of the type used for transparent wrappings.

viscose rayon See *rayon*.

viscosity η . The property of a *fluid* whereby it tends to resist relative motion within itself. If different layers of a fluid are moving with different *velocities*, *viscous forces* come into play, tending to slow down the faster-moving layers and to increase the velocity of the slower-moving layers. For two parallel layers in the direction of flow, a short distance apart, this viscous force is proportional to the velocity gradient between the layers (see *Newtonian fluid*). The constant of proportionality is called the coefficient of viscosity of the fluid. Viscosity is measured in *newton seconds per square metre* (*SI units*) or *poise* (*c.g.s. units*). $1 \text{ centipoise} = 10^{-3} \text{ N s m}^{-2}$ See also *kinematic viscosity*.

viscous Having high *viscosity*; a viscous *liquid* drags in a treacle-like manner.

visible spectrum The range of *electromagnetic radiations* that are visible to man. See *spectrum colours*.

visual binary A *binary star* system that can be resolved into two *stars* with an optical *telescope*. See also *spectroscopic binary*.

visual-display unit A *computer peripheral* device whose output is a *cathode-ray tube* for displaying text or diagrams. It may have an input device consisting of a keyboard or it may be a *light pen*.

visual purple See *rhodopsin*.

vitalistic theory The view that life, and all consequent biological phenomena, are due to a 'vital force'.

vitamins Accessory food factors. A group of organic substances, occurring in various foods, which are necessary for a normal diet. Absence or shortage leads to various deficiency diseases. Before the chemical nature of any of the vitamins was known, they were named by the letters of the alphabet. Vitamin A, $\text{C}_{20}\text{H}_{29}\text{OH}$, occurs in milk, butter, green vegetables, and in liver, especially of fish. Deficiency causes 'night-blindness' (see *rhodopsin*) and ultimately more serious eye troubles; the resistance of the mucous membranes to infection also decreases. This vitamin can be made in the body from *carotene*. Vitamin B, originally regarded as a single substance, has been shown to be a whole group of *compounds* termed the vitamin B complex; these occur in wheat-germ, yeast, and other sources. B_1 see *thiamin*; B_2 see *riboflavin* (also called vitamin G); B_6 see *pyridoxine*; B_{12} see *cyanocobalamin*; B_c see *folic acid* (also called vitamin M). See also other members of the complex, *nicotinic acid*, *inositol*, *pantothenic acid*, *choline*, and *biotin* (also called vitamin H). Vitamin C see *ascorbic acid*. Vitamin D consists of

VITREOSIL*

several compounds, all of which are *sterols*. The most important is *calciferol*. Vitamin E see *tocopherol*. Vitamin F see *linoleic acid*. Vitamin G (B_2) see *riboflavin*. Vitamin H see *biotin*. Vitamin K consists of naphthoquinone compounds whose deficiency causes haemorrhage. Vitamin M (B_c) see *folic acid*.

Vitreosil* A translucent form of *silica*, SiO_2 , prepared from sand. Used for making laboratory apparatus that is required to withstand large and sudden changes in *temperature*; it does not crack at such changes owing to its very low expansion.

vitreous Pertaining to, composed of, or resembling *glass*.

vitriol Concentrated *sulphuric acid*, H_2SO_4 , oil of vitriol; *copper sulphate*, $CuSO_4 \cdot 5H_2O$, blue vitriol; *ferrous sulphate*, $FeSO_4 \cdot 7H_2O$, green vitriol; *zinc sulphate*, $ZnSO_4 \cdot 7H_2O$, white vitriol.

volatile Passing readily into *vapour*; having a high *vapour pressure*.

volt The derived *SI unit* of electric *potential* defined as the difference of potential between two points on a conducting wire carrying a constant *current* of one *ampere* when the *power* dissipated between these points is one *watt*. Also the unit of *potential difference* and *electromotive force*. $1 \text{ volt} = 10^8 \text{ electromagnetic units}$. Symbol $V (= W/A)$. Named after Alessandro Volta (1745-1827).

voltage The *potential*, *potential difference*, or *electromotive force* of a supply of electricity, measured in *volts*.

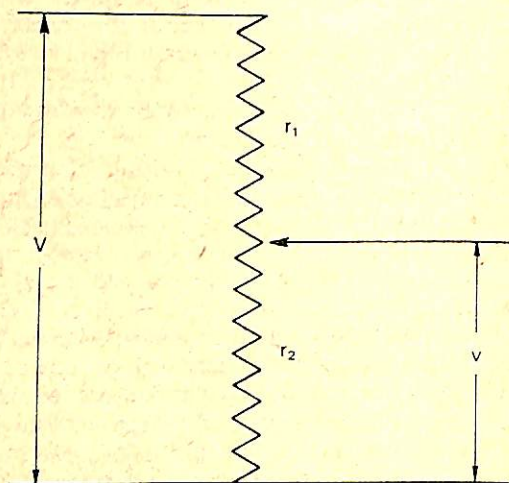


Figure 46.

voltage divider Potential divider, potentiometer. A *resistor* or series of resistors connected across a source of *voltage* (V) and tapped at a

point to give a fraction (v) of the total voltage. In Fig. 46, $v/V = r_2/(r_1 + r_2)$.

voltage doubler An *electronic circuit* that delivers a *direct current voltage* approximately twice the peak *alternating current* voltage it feeds on. It usually consists of two *rectifiers* whose outputs are connected in *series*.

voltaic cell See *cell* (phys.).

voltaic pile The earliest electric *battery*, devised by Volta. It consists of a number of *cells* joined in series, each consisting of a sheet of zinc and copper separated by a piece of cloth moistened with dilute *sulphuric acid*.

voltameter An electrolytic cell in which a *metal*, generally silver or copper, is deposited by *electrolysis* of a *salt* of the metal upon the *cathode*. From the increase in mass of the cathode and a knowledge of the *electrochemical equivalent* of the metal, the quantity of electricity that has passed through the circuit may be found.

voltmeter An instrument for measuring the *potential difference* between two points. In principle consists of an arrangement similar to an *ammeter* with a high *resistance* in series incorporated in the instrument, the scale being calibrated in *volts*. When the instrument is connected in parallel between the points at which the p.d. is being measured, very little current flows through it, and a correct reading of the *voltage* is obtained.

volume *V*. The measure of bulk or space occupied by a body.

volumetric analysis A group of methods of *quantitative chemical analysis* involving the measurement of *volumes* of the reacting substances. The amount of a substance present is determined by finding the volume of a *solution* of another substance, of known *concentration*, that is required to react with it. The added volume is measured by adding the reacting solution from a *burette*; the *end point* of the reaction is often shown by a suitable *indicator*.

vulcanite A hard insulating material made by the action of *rubber* on sulphur.

vulcanized rubber The product obtained by heating *rubber* with sulphur.

vulgar fraction Common fraction. A fraction expressed in terms of a *numerator* and a *denominator*, e.g. $\frac{3}{4}$.

Wankel rotary engine Epitrochoidal engine. A type of *internal-combustion engine* employing a 4-stroke cycle, but without reciprocating parts. It consists essentially of an elliptical combustion chamber fitted with valve-less inlet and outlet ports, and a conventional *sparking-plug*. An epicyclically-driven roughly triangular-shaped piston rotates within this chamber dividing it into three gas-tight sections, the volume of each of which varies as the piston rotates. The explosive mixture sucked in through the inlet port is compressed by the rotating piston and exploded by the sparking-plug. The explosion provides the power to rotate the piston and sweep the exhaust gases round to the outlet port. The small number of moving parts and the absence of vibration are the chief advantages of this type of engine. Named after Felix Wankel (b. 1902).

warfarin $C_{19}H_{16}O_4$. A colourless crystalline substance, m.p. 161°C ., used as a rat poison.

washing-soda Crystalline *sodium carbonate*, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

water H_2O . The normal *oxide* of hydrogen. Natural water (river, spring, rain, etc.) is never quite pure but contains dissolved substances. Pure water is a colourless, odourless *liquid*, m.p. 0°C ., b.p. 100°C ., which has a maximum *density* at 4°C . of 1.000 gram per cm^3 (1000 kg m^{-3}). Liquid water consists of associated *polar molecules*, $(\text{H}_2\text{O})_n$, with *hydrogen bonds* between the molecules.

water, expansion of Water on cooling reaches its maximum *density* at 3.98°C . when its density is $0.999\,973 \text{ g/cm}^3$; it then expands as its temperature falls to 0°C ., the density at 0° being $0.999\,841 \text{ g/cm}^3$; on freezing, it expands still further, giving *ice* with a density of 0.9168 g/cm^3 at 0°C . This accounts for the bursting of water-pipes in frosts.

water equivalent (phys.) See *heat capacity*.

water gas A *fuel gas* obtained by the action of *steam* on glowing hot *coke*; the gas formed consists of *carbon monoxide* and hydrogen. The formation of water gas is accompanied by absorption of *heat* (an *endothermic* reaction); thus the coke is rapidly cooled and has to be reheated at intervals by a blast of hot air, which causes partial *combustion* and makes the coke incandescent again.

water glass See *sodium silicate*.

water of constitution The portion of *water of crystallization* that, in some *hydrated salts*, is retained more tenaciously than the rest. Thus, *cupric sulphate*, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, when heated to 100°C . loses 4 *molecules* of water of crystallization and becomes $\text{CuSO}_4 \cdot \text{H}_2\text{O}$, but the last molecule is retained till the temperature reaches 250°C .

water of crystallization A definite molecular proportion of water chemically combined with certain substances in the crystalline state; e.g. the *crystals* of *cupric sulphate* contain 5 *molecules* of water with every molecule of cupric sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

water softening The removal of the causes of hardness of water (see *hard water*). It generally depends on the *precipitation* or removal from *solution* of the *metals* the *salts* of which cause the hardness.

water vapour Water in the gaseous or *vapour* state; it is present in the *atmosphere* in varying amounts. See *humidity*.

watt The derived *SI* unit of power, equal to one *joule* per second. The energy expended per second by an unvarying *electric current* of 1 *ampere* flowing through a *conductor* the ends of which are maintained at a *potential difference* of 1 *volt*. Equivalent to 10^7 ergs per second. The power in watts is given by the product of the current in amperes and the potential difference in volts. 1000 watts = 1 *kilowatt*; 745.7 watts = 1 *horsepower*. Symbol W (= J/s). Named after James Watt (1736-1819).

wattage Power measured in *watts*.

wattmeter An instrument for the direct measurement of the *power*, in *watts*, of an electrical *circuit*.

watt-second A unit of *work* or *energy* equivalent to one *joule*. See also *kilowatt-hour*.

wave A periodic disturbance in a medium or in *space* that involves the elastic displacement of material particles or a periodic change in some physical quantity, such as *temperature*, *pressure*, *electric potential*, *electromagnetic field strength*, etc. See *wave motion*.

wave equation The *equation* of *wave mechanics* that gives mathematical expression to *wave motion*:

$$\nabla^2 \psi = 1/c^2 \cdot \delta\psi/\delta t^2$$

where ∇^2 is the *Laplace operator*, ψ is the *wave function*, c is the *velocity of light*, and t is the time at any instant. See also *Schrödinger's wave equation*.

wave form The shape of a *wave*, illustrated graphically by plotting the values of the periodic quantity against time.

wave front The locus of adjacent points in the path of a *wave motion* that possess the same *phase*.

wave function In *wave mechanics*, *orbital electrons* are not treated as particles moving in precisely defined *orbits*, but as 3-dimensional *standing wave* systems represented by a wave function, ψ , the magnitude of which represents the varying *amplitudes* of the wave system at various points around the *nucleus*. The volume containing all the points where ψ has an appreciable magnitude is called the *orbital* of the electron. Thus, according to *wave mechanics*, the precise position and *velocity* of an electron (which cannot be defined without error, see *uncertainty principle*) is replaced by a

WAVE GUIDE

probability that an electron, visualized as a particle, will be at a certain point in *space* at a particular instant of time. The *probability distribution* of electrons is proportional to the magnitude of ψ^2 . See also *wave equation*.

wave guide A hollow *metal conductor* through which *microwaves* may be propagated. Used extensively in *radar*.

wavelength λ . The distance between successive points of equal *phase* of a wave; e.g. the wavelength of the waves on water could be measured as the distance from crest to crest. The wavelength is equal to the *velocity* of the wave motion divided by its *frequency*. For *electromagnetic radiation* $\lambda = c/v$, where c is the *velocity of light* and v is the frequency.

wave mechanics A development of *quantum mechanics*. Every particle is considered to be associated with a kind of periodic wave, whose *frequency* and *amplitude* are determined by rules (see *de Broglie wavelength*) derived partly by analogy with the propagation of *light waves*, partly by ad hoc hypothesis from known quantum conditions, and partly from necessary conditions of continuity. These waves, however, are not conceived as having any real physical existence, the term 'wave' being really used only by analogy as a description of the mathematical relations employed, since in all but the simplest cases the waves would have to be imagined in a 'hyperspace' of very many dimensions. Wave mechanics is based on *Schrödinger's wave equation* relating the energy of a system to its *wave function*, only certain values for which are allowed (see *eigenfunction*).

wavemeter An instrument for measuring the *wavelength* of a *radio frequency electromagnetic radiation*.

wave motion The propagation of a periodic disturbance carrying *energy*. At any point along the path of a wave motion, a periodic displacement or vibration about a mean position takes place. This may take the form of a displacement of air *molecules* (e.g. *sound waves* in air), of water molecules (waves on water), a displacement of elements of a string or wire, displacement of electric and magnetic *vectors* (*electromagnetic waves*), etc. The locus of these displacements at any instant is called the *wave*. The wave motion moves forward a distance equal to its *wavelength* in the time taken for the displacement at any point to undergo a complete cycle about its mean position. See *longitudinal waves*; *transverse waves*.

wave number $\sigma = 1/\lambda$. The number of waves in unit length. It is the reciprocal of *wavelength*.

wave theory of light The theory that *light* is propagated as a *wave motion* (see *electromagnetic radiation*), formerly the existence of a medium, the *ether*, was postulated for the transmission of light waves. This hypothesis has been rejected as unnecessary, and the classical wave theory has been modified to include the dual particle

(*photon*) wave concept, which is required to explain all the observed phenomena.

wax True waxes (e.g. *beeswax*) are simple *lipids* consisting of *esters* of higher *fatty acids* than are found in *fats and oils*, with *monohydric alcohols*. The term is often loosely applied to *solid*, non-greasy, *insoluble* substances that soften or melt at fairly low *temperatures*, e.g. *paraffin wax*.

weak acid An *acid*, such as *acetic acid*, that is only partly dissociated in solution. Compare *strong acid*.

weak electrolytes See *electrolytic dissociation, theory of*.

weak interactions An interaction between *elementary particles* that is some 10^{12} times weaker than *strong interactions*. *Beta decay* is a form of weak interaction. It is thought that such interactions are the result of an exchange of virtual particles (see *virtual state*) called *intermediate vector bosons*.

weber The derived *SI unit* of *magnetic flux* defined as the flux that, linking a circuit of one turn, produces in it an *E.M.F.* of one *volt* as it reduces to zero at a uniform rate in one *second*. Symbol Wb (= Vs). 1 weber = 10^8 *maxwells*. Named after Wilhelm Weber (1804-91).

Weidemann-Franz law The ratio of the *thermal conductivity* to the *electrical conductivity* is the same for all *metals* at a given *temperature*. This ratio is proportional to the *absolute temperature*. Most pure metals obey the law with reasonable accuracy at ordinary temperatures.

weight The *force of attraction* of the *Earth* on a given *mass* is the weight of that mass. Being a force, weight is correctly measured in units of force, such as the *newton*. The weight of a mass m , being equal to mg , where g is the *acceleration of free fall*. Thus the weight of a body depends on its geographical position (because of the variation in the value of g). The weight of a body is sometimes loosely expressed in units of mass, though this is not correct scientifically.

weight, British units of Avoirdupois weights.

437½ grains = 1 ounce.

7000 grains = 16 ounces = 1 *pound* = 0.453 592 *kilogram*

14 pounds = 1 stone.

2 stone = 1 quarter.

4 quarters = 1 hundredweight.

2000 pounds = 1 short ton. = 1 ton.

2240 pounds = 20 cwt

See Appendix, Table 1.

weight, metric units of

1000 milligrams = 1 gram = 15.432 grains

WELDING

1000 grams = 1 kilogram = 2.204 62 lb.
1000 kilograms = 1 tonne = 0.984 207 ton.

See Appendix, Table 1.

welding Joining of two *metal* surfaces by raising their *temperature* sufficiently to melt and fuse them together.

Weston cell Cadmium cell. A *primary cell* used as a standard of *E.M.F.* It produces 1.0186 volts at 20°C. It consists of a mercury *anode* covered with mercurous sulphate and a cadmium *amalgam* *cathode* coated with cadmium sulphate *crystals*. The *electrolyte* is a *saturated solution* of cadmium sulphate.

wet and dry bulb hygrometer An instrument for determining the *relative humidity* of the *atmosphere*. It consists of a pair of *thermometers* side by side, the bulb of one being surrounded by moistened muslin. This one will indicate a lower temperature than the other, on account of loss of *heat* by *evaporation*; the difference in the readings will depend upon the relative humidity, which can be found by reference to special tables calculated for the purpose.

wetting agent A substance that lowers the *surface tension* of a *liquid*.

whale oil Animal *fat* obtained from the fatty layer of blubber of true whales. After extraction it is divided into various fractions and used for *soap* manufacture and other purposes; on *hydrogenation* a hard tasteless edible fat is obtained.

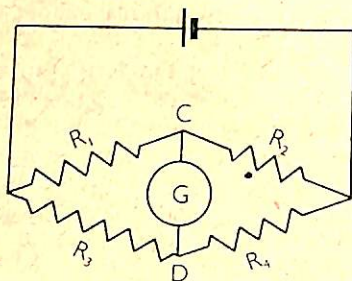


Figure 47.

Wheatstone bridge A divided electrical *circuit* used for the measurement of *resistances*. When no current flows from C to D , as indicated by the absence of deflection on the *galvanometer* G , $R_1/R_2 = R_3/R_4$, where R_1 , etc., are resistances. See Fig. 47. This principle is applied in the metre bridge. A wire, AB , of uniform resistance and generally 1 metre in length, corresponds to R_3 and R_4 in the Wheatstone bridge diagram; for R_1 a standard resistance is used, while R_2 is the resistance to be measured. By a sliding contact a point of no deflection in the galvanometer is found along

AB, the resistances R_3 and R_4 being proportional to the lengths cut of. Named after Sir Charles Wheatstone (1802-75).

whistler An *atmospheric* whistle of descending *pitch* that can be picked up under certain circumstances by a *radio* receiver. It is caused by *electromagnetic radiations*, produced by *lightning* flashes, which follow the *lines of force* of the Earth's *magnetic field* and are reflected back to Earth by the *ionosphere*.

white arsenic See *arsenic trioxide*.

white bronze *Bronze* that contains a high proportion of tin.

white dwarf A class of small, highly dense *stars* of low *luminosity*. They are the remnants of stars that have consumed nearly all their available hydrogen. Owing to their small size they have high surface *temperatures* and therefore appear white. See *supernovae*.

white lead See *lead carbonate*.

white light *Light* that can be resolved into a continuous *spectrum* of *wavelengths* (i.e. *colours*); e.g. the light from an incandescent 'white-hot' solid.

white spirit A *mixture* mainly of *alkanes* of boiling range 150°-200°C. Used as a *solvent* and in the *paint* and *varnish* industry.

wide-angle lens A *camera lens* with a wide angle of view (up to 100°) and a short *focal length*.

Wien displacement The maximum value of the product of the *absolute temperature* and the wavelength at which maximum emission occurs from a *black body* is displaced towards shorter wavelengths as the temperature increases. Named after Wilhelm Wien (1864-1928).

Wigner effect The effect produced when the *atoms* in a *crystal* are displaced as a result of *irradiation*. If *graphite*, for example, is bombarded with *neutrons*, the shape of the crystal *lattice* is altered and the material suffers a change of physical dimensions. See also *Wigner energy*. Named after Eugene Paul Wigner (born 1902).

Wigner energy *Energy* stored within a crystalline substance as a result of the *Wigner effect*. In a *nuclear reactor* in which *graphite* is used as the *moderator*, some of the energy lost by the *neutrons* is stored in the graphite; this is known as the *Wigner energy*.

Wigner nuclides Pairs of *isobars* of odd *mass number* in which the *atomic number* and *neutron number* differ by one E.g. ^3_1H and ^3_2He .

Wilson cloud chamber See *cloud chamber*. Named after C. T. R. Wilson (1869-1961).

Wimshurst machine A laboratory apparatus for generating static *electricity*. It consists of two insulating discs rotating in opposite directions. The charge, produced by friction, is collected by metal combs. Named after J. Wimshurst (1836-1903).

wind A large-scale movement of air, generally caused by a *convection* effect in the *atmosphere*.

WINDOW

window A wavelength band to which a particular medium is transparent. The atmosphere, for example, has a radio window in the range 8mm-20m.

wireless See *radio*.

wolfram W. See *tungsten*.

wolframite 'Wolfram'. Natural ferrous tungstate, FeWO_4 .

Wollaston prism A *prism* for obtaining plane-polarized light (see *polarization of light*). Constructed of *quartz*, this prism, like the *Rochon prism*, may be used for *ultraviolet radiation*. Named after W. H. Wollaston (1766-1828).

wood naphtha See *methanol*.

wood's metal An *alloy* of 50% bismuth, 25% lead, 12.5% tin, 12.5% cadmium. M.p. 71°C .

wood sugar See *xylose*.

woofers A *loudspeaker* designed to reproduce the lower *audio-frequency* sounds.

word The smallest number of *bits* of information that a particular *computer* can conveniently process as a single unit; usually 12 to 64 bits.

work (phys.) The work done by a *force* f when it moves its point of application through a distance s is equal to $fs \cos \theta$, where θ is the *angle* between the line of action of the force and the displacement. The derived *SI unit* of work is the *joule*; other units include *erg*, *foot-pound*, *foot-poundal*.

work function 1. At the *absolute zero* of temperature, the *free electrons* present in a *metal* are distributed amongst a large number of discrete *energy states* E_1 , E_2 , etc., up to a state of maximum energy E . At higher temperatures a small proportion of the electrons have energies greater than E . The work function of a metal is the energy that must be supplied to free electrons possessing energy E , to enable them to escape from the metal. 2. *Helmholtz free energy*.

work hardening See *strain hardening*.

working stress See *ultimate stress*.

wort See *brewing*.

ω -particle See *intermediate vector boson*.

wrought iron The purest commercial form of iron; iron nearly free from carbon. It is very tough and fibrous and can be welded.

X

xanthates *Salts or esters of the series of xanthic acids that have the general formula ROCSSH. Cellulose xanthate is the important intermediate product in the manufacture of viscose.*

xanthene Dibenzo-1,4-pyran. $C_6H_4O.CH_2C_6H_4$. A yellow crystalline *heterocyclic* compound, m.p. $100.5^\circ C.$, which forms the basis of the xanthene dyes.

xanthine 2,6-dioxypurine. $C_5H_4N_4O_2$. A yellow *soluble heterocyclic* compound, found in urine, *blood*, and certain animal *tissues*.

xanthone $C_6H_4.CO.O.C_6H_4$. A yellow *insoluble* crystalline *ketone*, m.p. $174^\circ C.$, that occurs in several natural yellow *pigments*.

xenon Xe. Element. A.W. 131.3. At. No. 54. An *inert gas* occurring in exceedingly minute amounts in the air (about 0.006 parts per million by volume). Used in filling certain types of *thermionic valves*, *fluorescent tubes*, and light bulbs.

xerography A method of photographic copying in which an electrostatic image is formed on a surface coated with selenium when it is exposed to an optical image. A dark powder (consisting of *graphite* and a *thermoplastic resin*), oppositely charged to the electrostatic image, is dusted on to the surface after exposure so that particles adhere to the charged regions; the image thus formed is then transferred to a sheet of charged paper and fixed by heating.

X-radiation *Electromagnetic radiation consisting of X-rays.*

X-ray crystallography The study of crystalline substances by observation of the *diffraction* patterns that occur when a *beam of X-rays* is passed through a *crystal*. It is principally as a result of the use of X-ray crystallography that the structure of certain *proteins* (e.g. *haemoglobin*) and *nucleic acids* has been analysed.

X-ray diffraction See *X-ray crystallography*.

X-rays Röntgen rays. *Electromagnetic radiations of the same type as light*, but of much shorter *wavelength*, in the range of 5×10^{-9} metre to 6×10^{-12} metre approximately. They are produced when a stream of *electrons* strikes a material object. X-rays affect a photographic plate in a way similar to light. The absorption of the rays by *matter* depends upon the *density* and the *atomic weights* of the material. The lower the A.W. and density, the more *transparent* is the material to X-rays. Thus, bones are more opaque than the surrounding flesh; this makes it possible to take an X-ray photograph (*radiograph*) of the bones of a living person.

X-ray spectrum Each *element*, when bombarded by *electrons*, emits *X-rays* of a characteristic *frequency*, which depends upon the *atomic*

X-RAY STARS

number; a photograph of the *line spectrum* corresponding to various elements may thus be obtained from the X-rays emitted.

X-ray stars Stars that emit X-rays: they were discovered by instruments carried outside the *Earth's atmosphere* by *space probes*. The nature of the stars, or their mechanism of X-ray emission, is not known.

X-ray tube An evacuated tube for producing X-rays, which contains an *electron gun* and a heavy *metal* target forming part of a massive *anode*. The metal emits X-rays when it is bombarded by high-energy *electrons*. The *spectrum* of the radiation depends on the *voltage* between the *cathode* and the anode, the *temperature* of the cathode, and the metal of the target.

X unit X.U. Unit of length, 10^{-11} cm. Used mainly for expressing X-ray *wavelengths*.

xylan A complex *polysaccharide* that occurs closely associated with *cellulose* in plants.

xylene Xylol, dimethylbenzene. $C_6H_4(CH_3)_2$. A *liquid* resembling *toluene* that occurs in *coal-tar*. It exists in three *isomeric* forms, a *mixture* of which boils at 137° - 140° C. Used in the manufacture of *dyes*.

xyloidine Dimethylaniline. $(CH_3)_2C_6H_3NH_2$. An aromatic amine that exists in six *isomeric* forms, of which five are liquids above $20^{\circ}C$.; b.p. in the range 216° - $230^{\circ}C$. Used in the manufacture of *dyes*.

xylol See *xylene*.

Xylonite* Trade name for a *plastic* material of the *cellulose nitrate* type. See also *celluloid*.

xylose Wood sugar. $C_5H_{10}O_5$. A colourless crystalline *pentose*, m.p. $144^{\circ}C$., found in *xylan*.

xylyl The *univalent radical* $CH_3C_6H_4CH_2-$.

xylylene The *bivalent radical* $-H_2CC_6H_4CH_2-$.

Y

Yagi aerial A directional *aerial* consisting of one or two *dipoles*, a parallel reflector, and a series of directors in front of the dipole, all so arranged that *radiation* is focused on to the dipole. Used in *television* and *radio astronomy*. Named after Hidetsuga Yagi (b. 1886).

yard British unit of length. The Imperial standard yard used to be defined as the distance, at 62°F., between the central traverse lines on two gold plugs in a certain *bronze* bar. The yard was redefined by the 1963 Weights and Measures Act as 0.9144 *metre*.

year A measure of time, commonly understood to be the time taken by the *Earth* to complete its *orbit* round the *Sun*. The civil year has an average value of 365.2425 mean *solar days*; 3 successive years consisting of 365 days, the fourth or leap year of 366. Century years do not count as leap years unless divisible by 400. The tropical, astronomical, or solar year, the average interval between two successive returns of the Sun to the first point of Aries, is 365.2422 mean solar days; the sidereal year, the interval in which the Sun appears to perform a complete revolution with reference to the fixed stars, is 365.2564 mean solar days. The anomalistic year, the average period of revolution of the Earth round the Sun from *perihelion* to perihelion, is 365.2596 mean solar days.

yeasts *Unicellular microorganisms* producing *zymase*, which converts *sugars* into *alcohol* and *carbon dioxide*. Used in *brewing* for the production of alcohol, and in baking because the carbon dioxide produced causes the dough to 'rise'.

yield point If a wire or rod of a material, such as *steel*, is subjected to a slowly increasing tension, the elongation produced is at first proportional to the tension (*Hooke's law*). If the tension is increased beyond the *elastic limit*, a point is reached at which a sudden increase in elongation occurs with only a small increase in tension; this is the yield point.

Young's modulus *Elastic modulus* applied to a stretched wire or to a rod under tension or compression; the ratio of the *stress* on a cross-section of the wire or rod to the longitudinal *strain*. Named after Thomas Young (1773-1829).

yperite See *mustard gas*.

ytterbium Yb. Element. A.W. 173.04. At. No. 70. R.d. 6.97, m.p. 1193°C. See *lanthanides*.

yttrium Y. Element. A.W. 88.905. At. No. 39. R.d. 4.457, m.p. 1523°C.

Z

Zeeman effect When a substance that emits a *line spectrum* is placed in a strong *magnetic field*, the single lines are split up into groups of closely spaced lines. From the separation of the lines in these groups information on atomic structure can be deduced. Named after Pieter Zeeman (1865-1943).

Zener current The current in a *semiconductor*, consisting of *electrons* that have escaped from the *valence band* into the *conduction band* under the influence of a strong *electric field*. Named after C. M. Zener (b. 1905).

zenith (astr.) The highest point; the point on the *celestial sphere* directly overhead. See Fig. 2 under *celestial sphere*, which also illustrates the 'zenith angle'.

zeolites A large class of *aluminosilicates*, both natural and synthetic, used for *ion exchange* and as adsorbents.

zero Nought; the starting-point of any scale of measurement.

zero point energy The *energy* possessed by the *atoms* or *molecules* of a substance at the *absolute zero* of temperature.

zerovalent Having zero *valence*.

ZETA Zero Energy Thermonuclear Apparatus. A *torus-shaped* apparatus used for studying controlled *thermonuclear reactions* at Harwell.

zeta-potential See *electrokinetic potential*.

Ziegler catalysts *Catalysts* capable of initiating the *polymerization* of *ethylene* and *propylene* at normal *temperatures* and *pressures*, e.g. titanium trichloride and aluminium alkyl. Named after Carl Ziegler (1897-1973).

zinc Zn. Element. A.W. 65.37. At. No. 30. A hard, bluish-white *metal*; m.p. 419°C.; b.p. 907°C.; r.d. 7.14. It occurs as *calamine*, ZnCO_3 , *zincite*, ZnO , and *zinc blende*, ZnS . The metal is extracted by roasting the ore to form the *oxide*, which is then reduced with carbon and the resulting zinc distilled. Used in *alloys*, especially *brass*, and in *galvanized iron*.

zincate A *salt* containing the ion ZnO_2^{2-} .

zinc blende Natural *zinc sulphide*, ZnS . An important *ore* of zinc.

zinc carbonate *Calamine*. ZnCO_3 . A white *insoluble* crystalline substance, used in medicine in the treatment of skins.

zinc chloride ZnCl_2 . A white *deliquescent soluble* substance, m.p. 283°C., used as an *antiseptic*, a wood preservative, and as a *flux*.

zinc-copper couple Metallic zinc coated with a thin film of copper by immersing zinc in *copper sulphate solution*. It evolves hydrogen with hot *water*.

- zincite** Natural *zinc oxide*, ZnO . An important ore of zinc.
- zinc oxide** ZnO . A white *amorphous* powder, m.p. 1975°C ., widely used as a *pigment*, in *glass* manufacture, in cosmetics, and in medicine.
- zinc phosphide** Zn_3P_2 . A grey *insoluble* crystalline substance, used as a rat poison.
- zinc silicate** Several silicates of zinc exist. Natural zinc silicate, hemimorphite, is $2\text{ZnO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$ (see also *calamine*). Zinc *metasilicate*, ZnSiO_3 , has m.p. 1437°C . Zinc *orthosilicate*, Zn_2SiO_4 , has m.p. 1509°C .
- zinc sulphate** White vitriol. $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$. A white *soluble* crystalline powder, m.p. 100°C ., used as a *mordant*, in zinc plating, in the manufacture of *paper*, and in medicine.
- zinc sulphide** ZnS . A white or yellowish *insoluble* crystalline substance that occurs naturally as *zinc blende*. Used as a *pigment*.
- zircon** Zirconium silicate. ZrSiO_4 . A colourless or yellowish *insoluble* substance, m.p. 2550°C . Used as a gemstone when *transparent* and a *refractory* when coloured.
- zirconia** See *zirconium dioxide*.
- zirconium** Zr. Element. A.W. 91.22. At. No. 40. A rare *metal*, r.d. 6.506, m.p. 1852°C . Used in *alloys*, *abrasives*, and flame proofing compounds.
- zirconium dioxide** Zirconia. ZrO_2 . A white crystalline *insoluble* substance, m.p. 2715°C ., used as a *pigment* and a *refractory*. The *hydrated* form, $\text{ZrO}_2 \cdot x\text{H}_2\text{O}$, also known as 'zirconium hydroxide' and 'zirconic acid', is a white *amorphous* powder.
- zirconyl** The *univalent* group $\text{ZrO}-$.
- zodiac** The zone of the *celestial sphere* that contains the paths of the Sun, the Moon, and the planets. It is bounded by two circles, which are equidistant from the *ecliptic* and about 18° apart. It is divided into the 12 signs of the zodiac, which are named after the 12 constellations.
- zodiacal light** A faint luminous patch seen in the sky, on the western horizon after sunset or on the eastern horizon before sunrise, believed to be due to the *scattering* of sunlight by meteoric matter revolving round the Sun.
- zone of sphere** A portion of the surface of a *sphere* cut off by two parallel *planes*. Its area is given by $2\pi rd$, where r is the radius of the sphere and d the distance between the two planes.
- zone refining** A purification method, applied mainly to metals, based on the principle that the solubility of an impurity B in a main component A in the solid state may differ from the solubility of B in A in the liquid state. When a narrow molten zone is made to pass (e.g. by movement of a heater outside a tube containing a long bar of the material) along a bar of impure A, the distribution of B between the solid and liquid material alters so that the impurity B

ZONES, FRESNEL

tends to segregate towards one end of the bar, with pure material at the other end.

zones, fresnel See *half-period zones*.

zones of audibility An intense *sound*, e.g. due to an *explosion*, can usually be heard or detected at all points in a large area around the source of the sound, and also in distant zones of audibility separated from that area by regions in which the sound cannot be detected. Sound waves can reach these zones by reflection down from the *upper atmosphere*.

zoology The scientific study of animals.

zoom lens A cinematic or television *camera lens* whose *focal length* can be adjusted continuously to vary the *magnification* without loss of focus.

zwitterion An *ion* carrying both a positive and negative *electric charge*.

zygote A fertilized *ovum*; the product of the union of two *gametes*.

zymase An *enzyme* present in *yeast* that acts on *sugar* with the formation of *alcohol* and *carbon dioxide*. See *fermentation*.

zymology Enzymology. The study of *fermentation* and the action of *enzymes*.

zymotic Relating to, or caused by, *fermentation*.

APPENDIX

TABLE I

6-FIGURE CONVERSION FACTORS
SI, CGS, AND FPS UNITS

<i>Length</i>	m	cm	in	ft	yd
1 metre	1	100	39.3701	3.28084	1.09361
1 centimetre	0.01	1	0.393701	0.0328084	0.0109361
1 inch	0.0254	2.54	1	0.0833333	0.0277778
1 foot	0.3048	30.48	12	1	0.333333
1 yard	0.9144	91.44	36	3	1

	km	mi	n.mi
1 kilometre	1	0.621371	0.539957
1 mile	1.60934	1	0.868976
1 nautical mile	1.85200	1.15078	1

1 light year = 9.46070×10^{15} metres = 5.87848×10^{12} miles.1 Astronomical Unit = 1.495×10^{11} metres.1 parsec = 3.0857×10^{16} metres = 3.2616 light years.

TABLE 1—cont.

6-FIGURE CONVERSION FACTORS
SI, CGS AND FPS UNITS

Area	m ²	cm ²	in ²	ft ²
1 square metre	1	10 ⁴	1550	10.7639
1 square centimetre	10 ⁻⁴	1	0.155	1.07639 × 10 ⁻³
1 square inch	6.4516 × 10 ⁻⁴	6.4516	1	6.94444 × 10 ⁻³
1 square foot	9.2903 × 10 ⁻²	929.03	144	1

	m ²	km ²	yd ²	mi ²	acre
1 square metre	1	10 ⁻⁶	1.19599	3.86019 × 10 ⁻⁷	2.47105 × 10 ⁻⁴
1 square kilometre	10 ⁶	1	1.19599 × 10 ⁶	0.386019	247.105
1 square yard	0.836127	8.36127 × 10 ⁻⁷	1	3.22831 × 10 ⁻⁷	2.06612 × 10 ⁻⁴
1 square mile	2.58999 × 10 ⁶	2.58999	3.0976 × 10 ⁶	1	640
1 acre	4.04686 × 10 ³	4.04686 × 10 ⁻³	4840	1.5625 × 10 ⁻³	1

1 are=100 square metres.

1 hectare=10 000 square metres=2.47105 acres.

TABLE 1. Conversion factors—*cont.*

<i>Volume</i>	m ³	cm ³	in ³	ft ³	gal
1 cubic metre	1	10 ⁶	6.10236 × 10 ⁴	35.3146	219.969
1 cubic centimetre	10 ⁻⁶	1	0.0610236	3.53146 × 10 ⁻³	2.19969 × 10 ⁻⁴
1 cubic inch	1.63871 × 10 ⁻⁵	16.3871	1	5.78704 × 10 ⁻⁴	3.60464 × 10 ⁻³
1 cubic foot	0.0283168	28316.8	1728	1	6.22882
1 gallon (UK)	4.54609 × 10 ⁻³	4546.09	277.42	0.160544	1

1 gallon (US)=0.832 68 gallon (UK).

1 cubic yard=0.764 555 cubic metre.

The *litre* is now recognized as a special name for a cubic decimetre, but is not used to express high precision measurements.

<i>Velocity</i>	m/sec	km/hr	mi/hr	ft/sec
1 metre per second	1	3.6	2.23694	3.28084
1 kilometre per hour	0.277778	1	0.621371	0.911346
1 mile per hour	0.44704	1.609344	1	1.46667
1 foot per second	0.3048	1.09728	0.681817	1

1 knot=1 nautical mile per hour=0.514 444 metre per second.

TABLE 1—*cont.*

6-FIGURE CONVERSION FACTORS

SI, CGS AND FPS UNITS

<i>Mass</i>	kg	g	lb	long ton
1 kilogram	1	1000	2.20462	9.84207×10^{-4}
1 gram	10^{-3}	1	2.20462×10^{-3}	9.84207×10^{-7}
1 pound	0.453592	453.592	1	4.46429×10^{-4}
1 long ton	1016.047	1.016047×10^6	2240	1

1 slug = 14.5939 kg = 32.174 lbs.

<i>Density</i>	kg/m ³	g/cm ³	lb/ft ³	lb/in ³
1 kilogram per cubic metre	1	10^{-3}	0.062428	3.61273×10^{-3}
1 gram per cubic centimetre	1000	1	62.428	3.61273×10^{-2}
1 pound per cubic foot	16.0185	0.0160185	1	5.78704×10^{-4}
1 pound per cubic inch	2.76799×10^4	27.6799	1728	1

1 lb/gal (UK) = 0.099 7763 kg/dm³.

<i>Force</i>	N	kg	dynes	poundal	lb
1 newton	1	0.101972	10^5	7.23300	0.224809
1 kilogram force	9.80665	1	9.80665×10^5	70.9316	2.20462
1 dyne	10^{-5}	1.01972×10^{-6}	1	7.23300×10^{-3}	2.24809×10^{-6}
1 poundal	0.138255	1.40981×10^{-2}	1.38255×10^4	1	0.031081
1 pound force	4.44822	0.453592	4.44823×10^5	32.174	1

TABLE 1. Conversion factors—cont.

<i>Pressure</i>	N/m^2 (Pa)	kg/cm^2	lb/in^2	atmos
1 newton per square metre (pascal)	1	1.01972×10^{-5}	1.45038×10^{-4}	9.86923×10^{-6}
1 kilogram per square centimetre	980.665×10^2	1	14.2234	0.967841
1 pound per square inch	6.89476×10^3	0.0703068	1	0.068046
1 atmosphere	1.01325×10^5	1.03323	14.6959	1

1 pascal = 1 newton per square metre = 10 dynes per square centimetre.

1 bar = 10^5 newtons per square metre = 0.986 923 atmosphere.

1 torr = 133.322 newtons per square metre = 1/760 atmosphere.

1 atmosphere = 760 mm Hg = 29.92 in Hg = 33.90 ft water (all at 0°C.).

Work and Energy

	J	cal_{17}	kWhr	btu_{17}
1 joule	1	0.238846	2.77778×10^{-7}	9.47813×10^{-4}
1 calorie (17)	4.1868	1	1.16300×10^{-6}	3.96831×10^{-3}
1 kilowatt hour	3.6×10^6	8.59845×10^5	1	3412.14
1 British Thermal Unit (17)	1055.06	251.997	2.93071×10^{-4}	1

1 joule = 1 newton metre = 1 watt second = 10^7 ergs = 0.737 561 ft lb.

1 electron volt = 1.602×10^{-19} joule.

TABLE 2. FUNDAMENTAL CONSTANTS

<i>Constant</i>	<i>Symbol</i>	<i>Value in SI Units</i>
electronic charge	e	$1.602\,192 \times 10^{-19} \text{ C}$
electronic rest mass	m_e	$9.109\,558 \times 10^{-31} \text{ kg}$
electronic radius	r_e	$2.817\,77 \times 10^{-15} \text{ m}$
proton rest mass	m_p	$1.672\,614 \times 10^{-27} \text{ kg}$
neutron rest mass	m_n	$1.674\,92 \times 10^{-27} \text{ kg}$
Planck's constant	h	$6.626\,196 \times 10^{-34} \text{ J s}$
velocity of light	c	$2.997\,925 \times 10^8 \text{ m s}^{-1}$
Avogadro constant	L, N_A	$6.022\,52 \times 10^{23} \text{ mol}^{-1}$
Loschmidt's constant	N_L	$2.687\,19 \times 10^{25} \text{ m}^{-3}$
gas constant	R	$8.314\,34 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann's constant	$k = \frac{R}{N_A}$	$1.380\,622 \times 10^{-23} \text{ J K}^{-1}$
Faraday constant	F	$9.648\,670 \times 10^4 \text{ C mol}^{-1}$
Stefan-Boltzmann constant	σ	$5.6697 \times 10^{-8} \text{ W m}^{-2} \text{ K}^4$
gravitational constant	G	$6.664 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	g	$9.806\,65 \text{ m s}^{-2}$
magnetic constant	μ_0	$4\pi \times 10^{-7} \text{ H m}^{-1}$
electric constant	ϵ_0	$8.854\,16 \times 10^{-12} \text{ F m}^{-1}$

TABLE 3. TABLE OF ELEMENTS, SYMBOLS, ATOMIC NUMBERS.
AND ATOMIC WEIGHTS

(International Atomic Weights, 1961, based on Carbon-12)

[A. W. values in brackets denote mass number of the most stable known isotope]

<i>Element</i>	<i>Symbol</i>	<i>At. No.</i>	<i>A. W.</i>
Actinium	Ac	89	[227]
Aluminium	Al	13	26.9815
Americium	Am	95	[243]
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.9216
Astatine	At	85	[210]
Barium	Ba	56	137.34
Berkelium	Bk	97	[247]
Beryllium	Be	4	9.0122
Bismuth	Bi	83	208.98
Boron	B	5	10.81
Bromine	Br	35	79.904
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.905
Calcium	Ca	20	40.08
Californium	Cf	98	[251]
Carbon	C	6	12.011
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.546
Curium	Cm	96	[247]
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	[254]
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	[257]
Fluorine	F	9	18.9984
Francium	Fr	87	[223]
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.967
Hafnium	Hf	72	178.49
Helium	He	2	4.0026
Holmium	Ho	67	164.930

TABLE 3. Table of elements, etc.—*cont.*

<i>Element</i>	<i>Symbol</i>	<i>At. No.</i>	<i>A.W.</i>
Hydrogen	H	1	1.00797
Indium	In	49	114.82
Iodine	I	53	126.9044
Iridium	Ir	77	192.2
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	[257]
Lead	Pb	82	207.19
Lithium	Li	3	6.939
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.305
Manganese	Mn	25	54.938
Mendelevium	Md	101	[258]
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.179
Neptunium	Np	93	[237]
Nickel	Ni	28	58.71
Niobium	Nb	41	92.906
Nitrogen	N	7	14.0067
Nobelium	No	102	[255]
Osmium	Os	76	190.2
Oxygen	O	8	15.9994
Palladium	Pd	46	106.4
Phosphorus	P	15	30.9738
Platinum	Pt	78	195.09
Plutonium	Pu	94	[244]
Polonium	Po	84	[209]
Potassium	K	19	39.102
Praseodymium	Pr	59	140.907
Promethium	Pm	61	[145]
Protactinium	Pa	91	[231]
Radium	Ra	88	[226]
Radon	Rn	86	[222]
Rhenium	Re	75	186.20
Rhodium	Rh	45	102.905
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.35
Scandium	Sc	21	44.956
Selenium	Se	34	78.96
Silicon	Si	14	28.086

TABLE 3. Table of elements, etc.—*cont.*

<i>Element</i>	<i>Symbol</i>	<i>At. No.</i>	<i>A.W.</i>
Silver	Ag	47	107.868
Sodium	Na	11	22.9898
Strontium	Sr	38	87.62
Sulphur	S	16	32.064
Tantalum	Ta	73	180.948
Technetium	Tc	43	[97]
Tellurium	Te	52	127.60
Terbium	Tb	65	158.924
Thallium	Tl	81	204.37
Thorium	Th	90	232.038
Thulium	Tm	69	168.934
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.942
Wolfram (Tungsten)	W	74	183.85
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.905
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

TABLE 4. THE SOLAR SYSTEM

<i>Planet</i>	<i>Equatorial Diameter (kilometres)</i>	<i>Mass (Earth masses)*</i>	<i>Mean Distance from Sun (millions of kilometres)</i>	<i>Sidereal period</i>
Mercury	4840	0.054	57.91	87.969 days
Venus	12 300	0.8150	108.21	224.701 days
Earth	12 756	1.000	149.60	365.256 days
Mars	6790	0.107	227.94	686.980 days
Jupiter	142 800	317.89	778.34	11.86 years
Saturn	119 300	95.14	1427.01	29.46 years
Uranus	47 100	14.52	2869.6	84.0 years
Neptune	44 800	17.46	4496.7	164.8 years
Pluto	5900	0.1 (approx.)	5907	248.4 years
Sun	1 392 000	332 958	149.60†	—
Moon	3476	0.0123	0.3844†	27.32

* The Mass of the Earth is 5.976×10^{24} kilogram.

† Distance to Earth.

TABLE 5. TABLE OF AMINO ACIDS

<i>Name</i>	<i>Formula</i>	<i>Molecular weight</i>
Glycine	$\text{CH}_2(\text{NH}_2).\text{COOH}$	75.1
Alanine	$\text{CH}_3\text{CH}(\text{NH}_2).\text{COOH}$	89.1
Phenylalanine	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	165.2
Tyrosine	$\text{C}_6\text{H}_4\text{OH}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	181.2
Valine	$(\text{CH}_3)_2\text{CH}.\text{CH}(\text{NH}_2).\text{COOH}$	117.1
Leucine	$(\text{CH}_3)_2\text{CH}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	131.2
Iso-leucine	$(\text{CH}_3).\text{CH}_2\text{CH}(\text{CH}_3).\text{CH}(\text{NH}_2).\text{COOH}$	131.2
Serine	$\text{CH}_2\text{OH}.\text{CH}(\text{NH}_2).\text{COOH}$	105.1
Threonine	$\text{CH}_3\text{CHOH}.\text{CH}(\text{NH}_2).\text{COOH}$	119.1
Cysteine	$\text{SH}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	121.1
Cystine	$[\text{HOOC}.\text{CH}(\text{NH}_2).\text{CH}_2\text{S}]_2$	240.3
Methionine	$\text{CH}_3.\text{S}(\text{CH}_2)_2\text{CH}(\text{NH}_2).\text{COOH}$	149.2
Asparagine	$\text{NH}_2\text{CO}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	132.1
Glutamine	$\text{NH}_2\text{CH}(\text{CH}_2)_2(\text{CO}.\text{NH}_2).\text{COOH}$	146.1
Lysine	$\text{NH}_2(\text{CH}_2)_4\text{CH}(\text{NH}_2).\text{COOH}$	146.2
Arginine	$\text{NH}_2\text{C}(\text{:NH}).\text{NH}(\text{CH}_2)_3\text{CH}(\text{NH}_2).\text{COOH}$	174.2
Aspartic	$\text{COOH}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	133.1
Glutamic	$\text{COOH}(\text{CH}_2)_2\text{CH}(\text{NH}_2).\text{COOH}$	147.1
Histidine	$\text{C}_3\text{H}_3\text{N}_2.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	155.2
Tryptophan	$\text{C}_6\text{H}_4.\text{NH}.\text{C}_2\text{H}.\text{CH}_2\text{CH}(\text{NH}_2).\text{COOH}$	204.2
Proline	$\text{NH}(\text{CH}_2)_3\text{CH}.\text{COOH}$	115.1

TABLE 6. ELEMENTARY PARTICLES

Class		Particle	Symbol	Charge	Spin	Mass (MeV)	Strange-ness	Lifetime (secs)
LEPTONS		Electron	e^-	-1	$\frac{1}{2}$	0.511		Stable
		Neutrino	ν	0	$\frac{1}{2}$	0		Stable
			ν_μ	0	$\frac{1}{2}$	0		Stable
		Muon	μ^-	-1	$\frac{1}{2}$	105.66		2.2×10^{-6}
HADRONS	NUCLEONS	Proton	p	+1	$\frac{1}{2}$	938.26	0	Stable
		Neutron	n	0	$\frac{1}{2}$	939.55	0	932
	BARYONS HYPERONS	Xi-particles	Ξ^0	0	$\frac{1}{2}$	1314.9	-2	2.9×10^{-10}
			Ξ^-	-1	$\frac{1}{2}$	1321.3	-2	1.7×10^{-10}
		Sigma-particles	Σ^+	+1	$\frac{1}{2}$	1189.5	-1	8.1×10^{-10}
			Σ^0	0	$\frac{1}{2}$	1192.5	-1	1×10^{-14}
			Σ^-	-1	$\frac{1}{2}$	1197.4	-1	1.66×10^{-10}
		Lambda-particle	Λ	0	$\frac{1}{2}$	1115.5	-1	2.5×10^{-10}
		Omega-particle	Ω^-	-1	$\frac{3}{4}$	1672.5	-3	1.3×10^{-10}
	MESONS	Eta-particle	ν^0	0	0	548.8	0	?
		Kaons	K^-	-1	0	493.8	-1	1.2×10^{-8}
			K^+	+1	0	493.8	+1	1.2×10^{-8}
		Pions	π^+	+1	0	139.6	0	2.6×10^{-8}
			π^0	0	0	135	0	1×10^{-16}
			π^-	-1	0	139.6	0	2.6×10^{-8}
		Phi	ϕ	0	1	1020	0	10^{-22}
		Psi	Ψ	0	1	3095	0	10^{-20}

TABLE 7. ELECTRON CONFIGURATIONS AND IONIZATION POTENTIALS OF THE COMMONER ELEMENTS

Element	Atomic Number	Electron Configuration Shell						Ionization Potentials (electron-volts)					
		1 K	2 L	3 M	4 N	5 O	6 P	I	II	III	IV	V	
H	1							13.59					
He	2							24.48	54.40				
C	6		2	4				11.26	24.38	47.87	64.48	392.0	
N	7		2	5				14.53	29.59	47.43	77.45	97.86	
O	8		2	6				13.61	35.11	54.89	77.39	113.9	
F	9		2	7				7.87	16.18	30.64	56.80	114.2	
Ne	10		2	8				21.56	41.07	63.50	97.02	126.3	
Na	11		2	8	1			5.14	47.29	71.71	98.88	138.4	
Mg	12		2	8	2			7.64	15.03	80.14	109.29	141.2	
Al	13		2	8	3			5.98	18.82	28.44	119.96	153.8	
Si	14		2	8	4			8.15	16.34	33.49	45.13	166.7	
P	15		2	8	5			10.48	19.72	30.16	51.35	65.0	
S	16		2	8	6			10.36	23.40	35.0	47.29	72.5	
Cl	17		2	8	7			13.01	23.80	39.9	53.50	67.8	
Ar	18		2	8	8			15.75	27.62	40.9	59.8	75.0	

TABLE 7. Electron configurations, etc. — cont.

TABLE 7. Electron configurations, etc. — cont.

Element	Atomic Number	Electron Configuration Shell										Ionization Potentials (electron-volts)				
		1 K	2 L	3 M	4 N	5 O	6 P	I	II	III	IV	V				
K	19	2	8	8	1			4.34	31.81	46.0	60.9	82.6				
Ca	20	2	8	8	2			6.11	11.87	51.2	67.0	84.4				
Fe	26	2	8	14	2			7.87	16.18	30.6	56.8	—				
Cu	29	2	8	18	1			7.72	20.30	36.8	—	—				
Zn	30	2	8	18	2			9.39	17.96	39.7	—	—				
Br	35	2	8	18	7			11.84	21.60	35.9	47.3	59.7				
Kr	36	2	8	18	8			13.99	24.50	36.9	43.5	63.0				
Ag	47	2	8	18	18	1		7.57	21.5	34.8	—	—				
Sn	50	2	8	18	18	4		7.34	14.63	30.5	40.7	72.3				
I	53	2	8	18	18	7		10.45	19.13	—	—	—				
Xe	54	2	8	18	18	8		12.13	21.2	31.3	42.0	53.0				
Cs	55	2	8	18	18	8	1	3.89	25.1	35.0	—	—				
Ba	56	2	8	18	18	8	2	5.21	10.0	35.5	—	—				
Hg	80	2	8	18	32	18	2	10.43	18.75	34.2	49.5	—				

TABLE 8. PERIODIC TABLE OF THE ELEMENTS

1A	2A	3B	4B	5B	6B	7B	8	1B	2B	3A	4A	5A	6A	7A	0		
1 H															2 He		
3 Li	4 Be									5 B	6 C	7 N	8 O	9 F	10 Ne		
11 Na	12 Mg									13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57* La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89† Ac															
*Lanthanides			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
†Actinides			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

TABLE 9. DIFFERENTIAL COEFFICIENTS AND INTEGRALS

y	$\frac{dy}{dx}$	$\int y \cdot dx$
x^n	nx^{n-1}	$\frac{1}{n+1} \cdot x^{n+1}$
$\frac{1}{x}$	$-\frac{1}{x^2}$	$\log_e x$
e^{ax}	ae^{ax}	$\frac{1}{a} \cdot e^{ax}$
$\log_e x$	$\frac{1}{x}$	$x(\log_e x - 1)$
$\log_a x$	$\frac{1}{x} \cdot \log_a e$	$x \cdot \log_a \frac{x}{e}$
$\cos ax$	$-a \cdot \sin ax$	$\frac{1}{a} \cdot \sin ax$
$\sin ax$	$a \cdot \cos ax$	$-\frac{1}{a} \cdot \cos ax$
$\tan ax$	$a \cdot \sec^2 ax$	$-\frac{1}{a} \cdot \log_e \cos ax$
$\cot x$	$-\operatorname{cosec}^2 x$	$\log_e \sin x$
$\sec x$	$\tan x \cdot \sec x$	$\log_e (\sec x + \tan x)$
$\operatorname{cosec} x$	$-\cot x \cdot \operatorname{cosec} x$	$\log_e (\operatorname{cosec} x - \cot x)$
$\sin^{-1} \frac{x}{a}$	$\frac{1}{(a^2 - x^2)^{\frac{1}{2}}}$	$x \cdot \sin^{-1} \frac{x}{a} + (a^2 - x^2)^{\frac{1}{2}}$
$\cos^{-1} \frac{x}{a}$	$\frac{-1}{(a^2 - x^2)^{\frac{1}{2}}}$	$x \cdot \cos^{-1} \frac{x}{a} - (a^2 - x^2)^{\frac{1}{2}}$
$\tan^{-1} \frac{x}{a}$	$\frac{a}{a^2 + x^2}$	$x \cdot \tan^{-1} \frac{x}{a} - a \log_e (a^2 + x^2)^{\frac{1}{2}}$

TABLE 10. SPECTRUM OF ELECTROMAGNETIC RADIATIONS

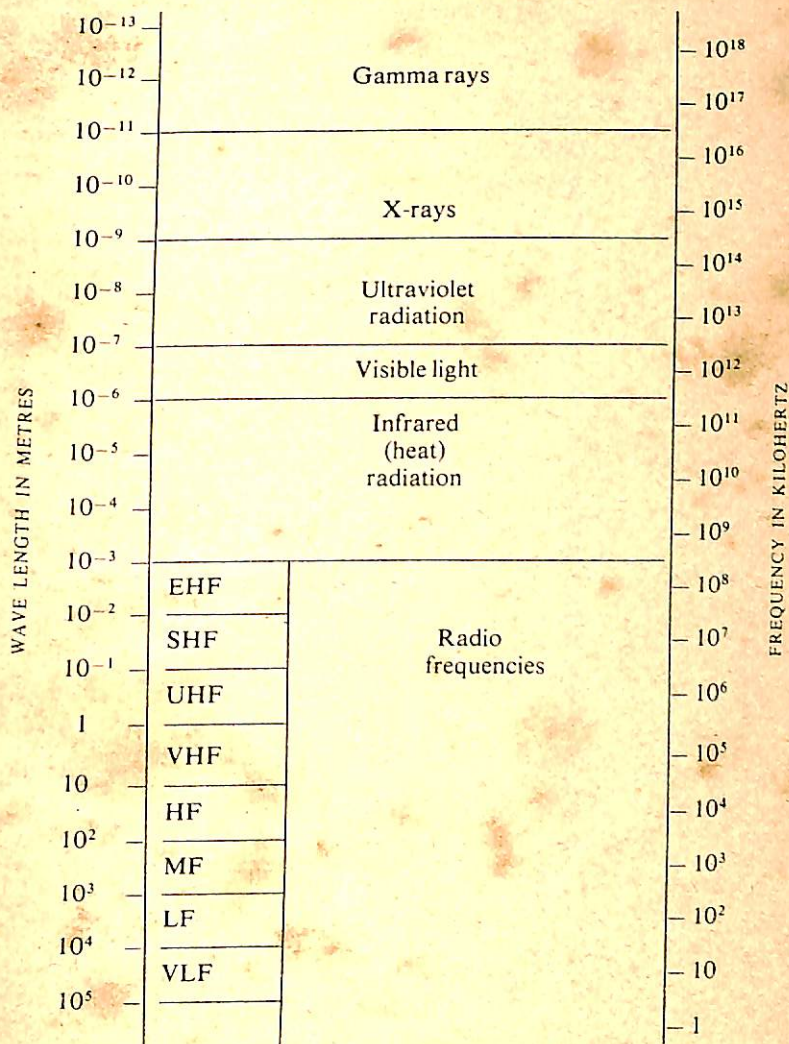


TABLE II. THE GREEK ALPHABET

<i>Letters</i>		<i>Name</i>
A	α	alpha
B	β	beta
Γ	γ	gamma
Δ	δ	delta
E	ϵ	epsilon
Z	ζ	zeta
H	η	eta
Θ	θ	theta
I	ι	iota
K	κ	kappa
Λ	λ	lambda
M	μ	mu
N	ν	nu
Ξ	ξ	xi
O	\omicron	omicron
Π	π	pi
P	ρ	rho
Σ	σ	sigma
T	τ	tau
Υ	υ	upsilon
Φ	ϕ	phi
X	χ	chi
Ψ	ψ	psi
Ω	ω	omega



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